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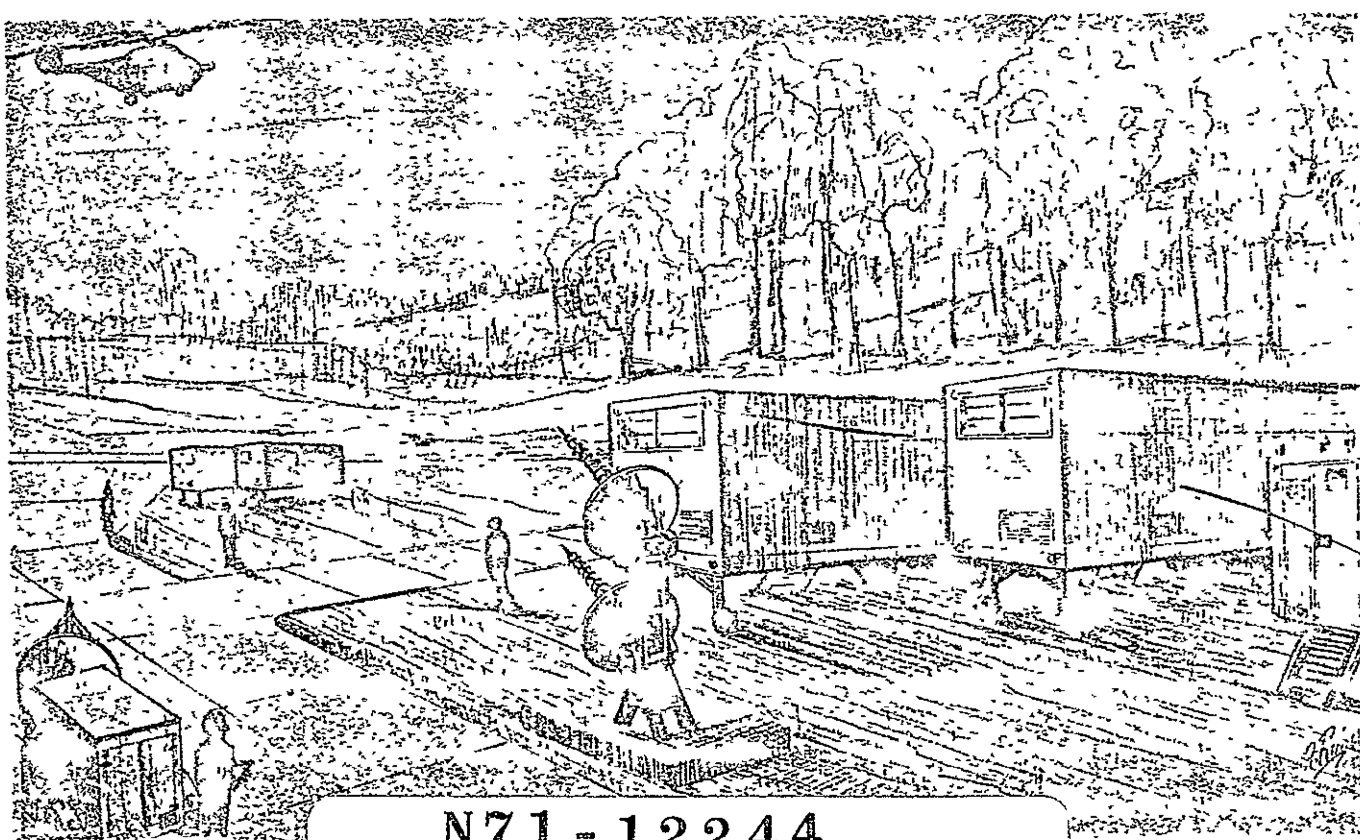
ERC V/STOL PROGRAM FLIGHT TEST PLAN

H-19 FLIGHT PROGRAM
PHASES IA AND IB
WALLOPS STATION, VIRGINIA



National Aeronautics and Space Administration
ELECTRONICS RESEARCH CENTER
Cambridge, Massachusetts

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H-19 FLIGHT PROGRAM PHASES 1A AND 1B WALLOPS STATION, VIRGINIA

May 1968

Approved by:

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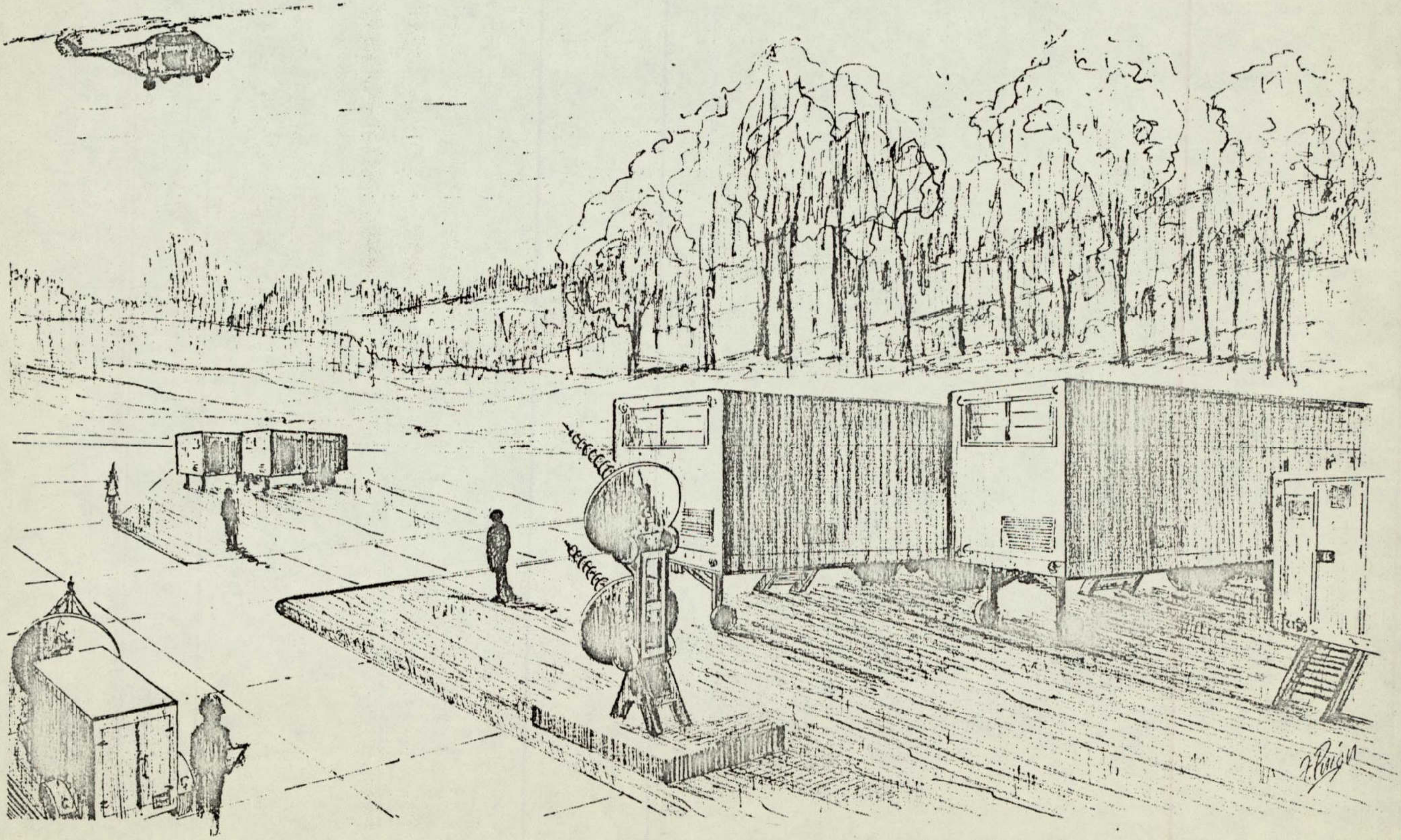
ELECTRONICS RESEARCH CENTER
Cambridge, Massachusetts



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ILLUSTRATIONS

1. SUMMARY

This document presents the general flight test plan for the first two phases of the H-19 flight test program. The document describes the test program and establishes guidelines for the detailed plans which will be documented in the procedures and operations manuals.

The tests will be conducted at Wallops Station, Virginia, during the period from June to December, 1968. Phase 1A will be devoted to total equipment flight checkout and individual performance measurements of the inertial subsystem and simulated navigation aid. Phase 1A will run from June to September . Aided inertial system tests will be conducted in Phase 1B which will run from September through December.

The major flight test objective to which this program is directed is to obtain experimental data on an aided inertial system for terminal guidance and navigation of a helicopter for use in designing a V/STOL avionics system. This plan defines: detailed objectives, success criteria, testing approach, system and instrumentation descriptions, flight profiles, test descriptions, facilities, data recovery, post-flight analysis, and schedules.

An experimental aided-inertial flight system, currently in the final development stage at ERC, will be utilized in the H-19 helicopter for making the necessary navigation measurements. The system utilizes a Gemini inertial guidance system combined with a GSN-5 radar/Gemini uplink to simulate navigation updates. The system is further described in Section 4.

Instrumentation to measure both inertial and navigation aid performance will consist of the Gemini Data Transmission Subsystem (DTS), onboard vibration sensors, the GSN-5 ground based radar, and ground based recorders, plotters and displays. Instrumentation is further detailed in Section 5.

Tests and experiments to meet the flight objectives are identified in some detail in Section 6. Five basic flight conditions or profiles are developed including ground navigation, hover, field proximity flights,

level flight cruise, and cruise exit update. Test descriptions covering the system preflight through flight are defined for both Phase 1A and 1B.

Field facilities, maps, layouts, van and equipment locations and basic operations are described in Section 7. Three basic test areas are involved in the test operations at Wallops Station. These include: Area 1, which includes the helicopter ramp, AGE van, operations van and alignment equipment; Area 2, which includes the DTS van, DCS van, auxiliary antenna platform, GSN-5 radar and GSN-5 radar van; and Area 3, the hangar.

The data recovery activities are covered in Section 8. Preliminary parameter lists provide for 41 parameters to be telemetered and flight recorded. The tape development and formatting approach is also defined. An approach for performing quick look and post-flight analysis is provided in Section 9.

A preliminary schedule of flight tests and experiments has been prepared and is included in Section 10. Approximately 106 successful flights will be required to meet the experimental objectives of the program.

2. INTRODUCTION

The H-19 program constitutes the first phase of ERC's V/STOL Avionics Research Program. The overall V/STOL program is directed toward the development of an all-weather avionics system for V/STOL. The H-19 program, designated Phase 1, will concentrate on the guidance and navigation area with particular emphasis placed on the most critical flight phase, that of terminal approach and landing.

A coordinated H-19 research effort has been planned and is currently in progress to investigate terminal guidance and navigation techniques with potential for V/STOL. The effort involves analysis, simulation, experimental hardware integration, laboratory testing, and flight testing of promising experimental G&N techniques. The H-19 flight tests, defined in this plan, are aimed at providing performance data which, in combination with the results of analysis and simulation, can be used to evaluate the feasibility of the aided-inertial approach for V/STOL. Information obtained in the H-19 test program will be utilized to plan more complete testing for advanced vehicles. In some cases, the information will be directly extrapolated to the V/STOL application.

The aided inertial navigation technique has been selected as the prime concept for investigation in the H-19 flight test program. The experimental system developed at ERC and identified in the previous section implements the aided inertial technique. The aided inertial approach was selected because of its experimental flexibility and because of its potential applicability in meeting the ultimate V/STOL terminal flight requirements.

A brief functional description of the system and roles played by each of the major elements is provided with the aid of Figure 2-1 to provide a basis for understanding the proposed H-19 experiments and flight tests discussed later in the plan. The system consists of three basic elements, including: a) an inertial measurement unit for making onboard velocity and position measurements, b) an external aid for making external velocity and position measurements, and c) a com-

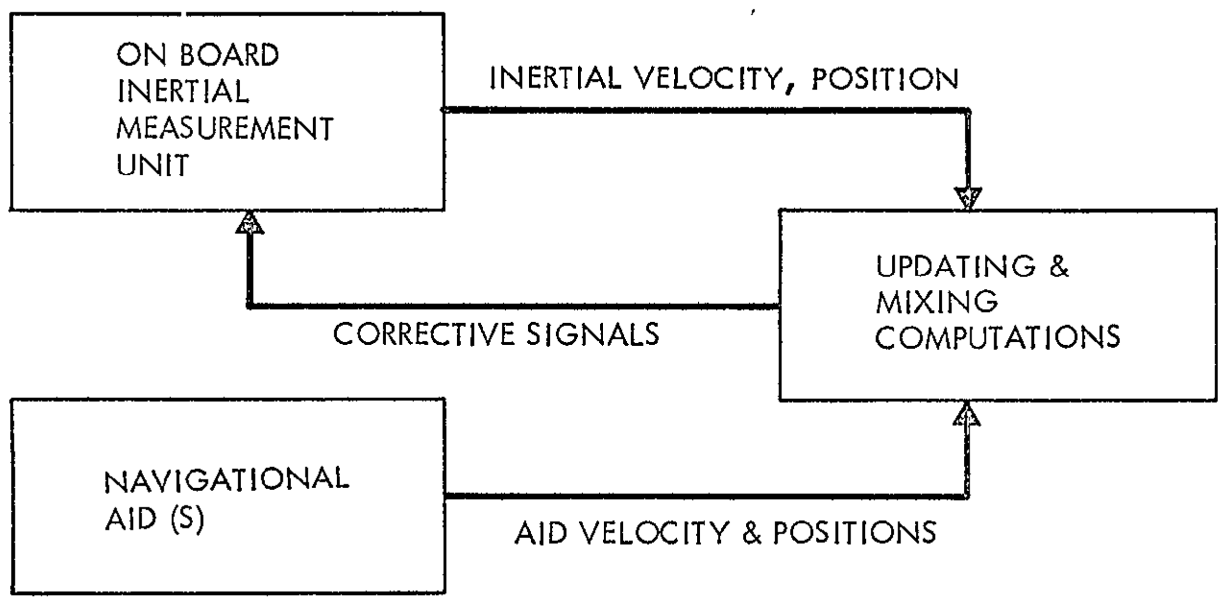

Figure 2-1. Aided Inertial Navigation Concept

puter-implemented mixing and updating scheme to combine the measurements to provide an improved measure of velocity and position (over that of the inertial or external measurements taken separately).

Generally stated, the H-19 experiments and flight tests are based on providing information which will eventually be used to establish requirements for the three basic elements (blocks) of Figure 2-1. Overall system performance will, of course, be affected by all three elements. For an ultimate V/STOL design, tradeoffs will have to be performed to provide an effective balance between performance, complexity, and cost of the inertial unit, navigation aid and update scheme. Flight tests will therefore be conducted to measure, first, individual performance of the inertial and aid subsystems and, eventually, overall system performance using combined measurements processed in the updating computations. Variations in performance as a function of flight conditions, time, etc., is particularly important to provide a base for extrapolating the H-19 flight test results to later applications.

The manner in which the inertial and aid measurements are to be used is of concern in formulating a V/STOL update scheme and establishing eventual subsystem requirements. The proposed experiments and flight tests to investigate this area can be put in perspective by examining some likely conditions for the V/STOL application. The V/STOL will be in a radio aid environment throughout flight affording the possibility of bounding the inertial system errors (i.e., velocity, position, misalignments and instrument errors). This will alleviate the updating that has to be done in the terminal approach phase.

There are several potential advantages of the aided approach:

- Although effort is being devoted to the improvement in navigational aids, a mixed navigation aid/inertial system has potential of being cost and mission-effective by permitting a wide range of design tradeoffs between the navigation aids and the inertial system.

- The altitude and altitude rate requirements for landing are most critical. Onboard altitude aids with high performance have been proven for conventional aircraft and are therefore likely for V/STOL. A combination of

inertial sensor damping with onboard altitude sensing has good potential for providing the required dynamic accuracy.

- The desirable V/STOL approach trajectories are more complicated than for conventional aircraft. The use of an aided inertial system affords potential trajectory flexibility (for both approaches and missed approaches) without continuous aid coverage.

To achieve the above potential advantages, two basic features of the aided inertial system must be examined and demonstrated.

- Navigation performance of the aided-inertial system must be demonstrated (allowing for potential improvement in updating aids).
- Performance variations as a function of update accuracy, frequency and geometry must be examined.

A typical experimental approach trajectory (generally representing V/STOL) and associated position error volumes is shown in Figure 2-2. The terminal approach begins with an exit from cruise followed by a terminal updating period and, finally, all inertial flight to touchdown. Separate experiments will be conducted covering the various regions and situations. Experiments simulating the final phase of cruise will be important since time is critical for effective updating, particularly for in-flight instrument compensation. Terminal updating will likely be limited to updating position and/or velocity only. The all-inertial period is important to assess the proximity of the final aid relative to the landing point.

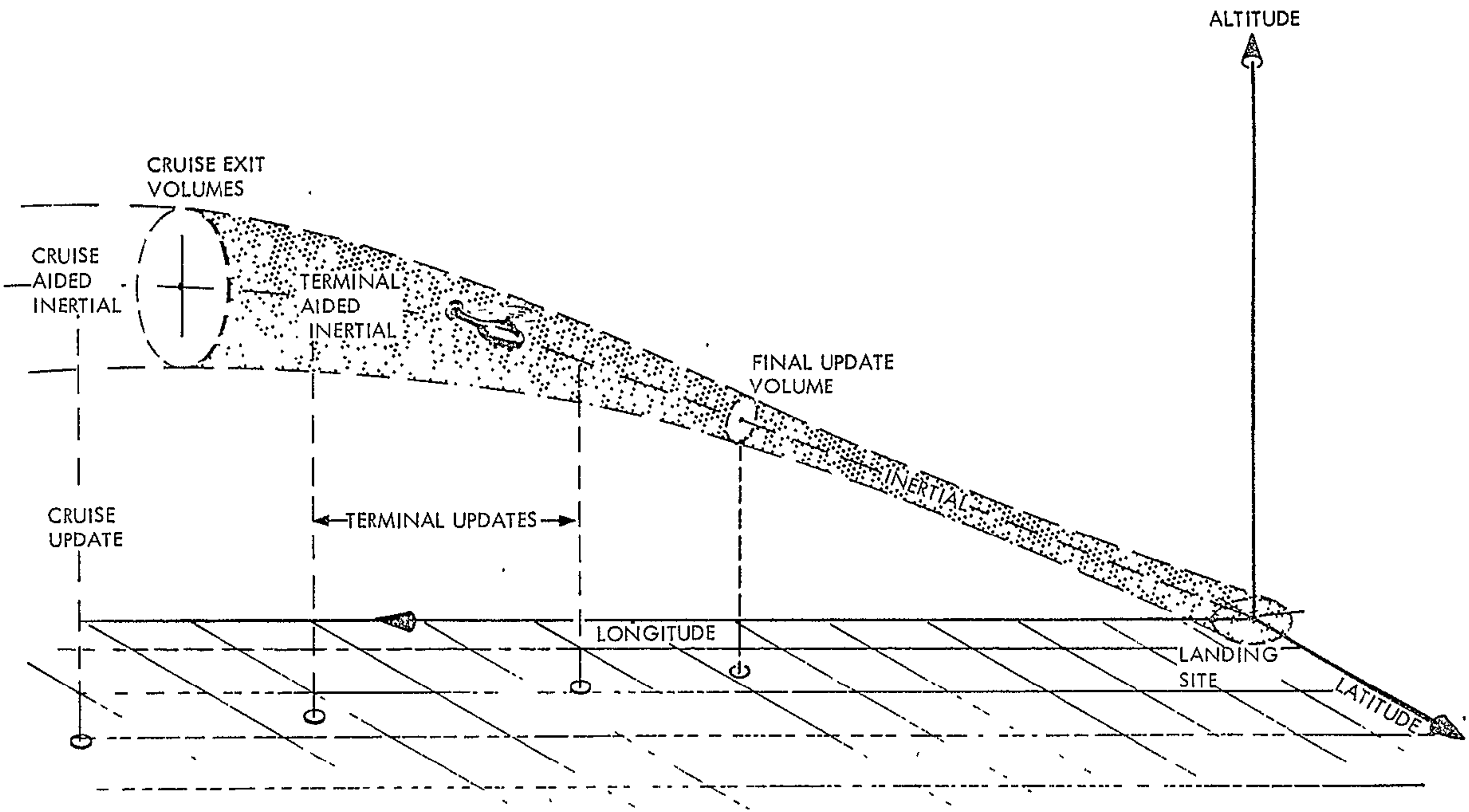

Figure 2-2. Typical Position Error Volumes

3. OBJECTIVES AND APPROACH

3.1 GENERAL PROGRAM OBJECTIVE

To evaluate the feasibility of using an IGS/Nav Aid system for terminal guidance and navigation of V/STOL.

3.2 FLIGHT TEST OBJECTIVE

To obtain experimental data from a Gemini IGS/GSN-5 Nav Aid system on an H-19 helicipter for use in determining design requirements for a V/STOL avionics system.

3.2.1 Phase 1A Flight Test Subobjectives

- Establish flight operability of all equipment required for Phases 1A and 1B.
- Establish (separately) Gemini IGS and GSN-5 radar performance in the H-19 environment for experimental profiles and flight conditions.

3.2.2 Phase 1B Flight Test Subobjectives

- Demonstrate flight operability of Gemini IGS/GSN-5 Nav Aid and update software for 1B experiments.
- Establish aided inertial terminal navigation performance in H-19 environment for simulated V/STOL flight profiles and conditions.

3.3 APPROACH

The general approach to the test and evaluation program is shown in Figure 3.1. The test program will be conducted in two phases, identified as Phase 1A and Phase 1B. Checkout of all equipment for both phases will be accomplished in Phase 1A. Actual updating of the IGS with uplink data will be accomplished during Phase 1B utilizing revised software which will be developed during 1A. Tests and related analyses will be performed as follows:

3.3.1 Phase 1A

- Ground and flight tests by subsystem and system to shake down and establish the operability of all equipment in the test environment, including:

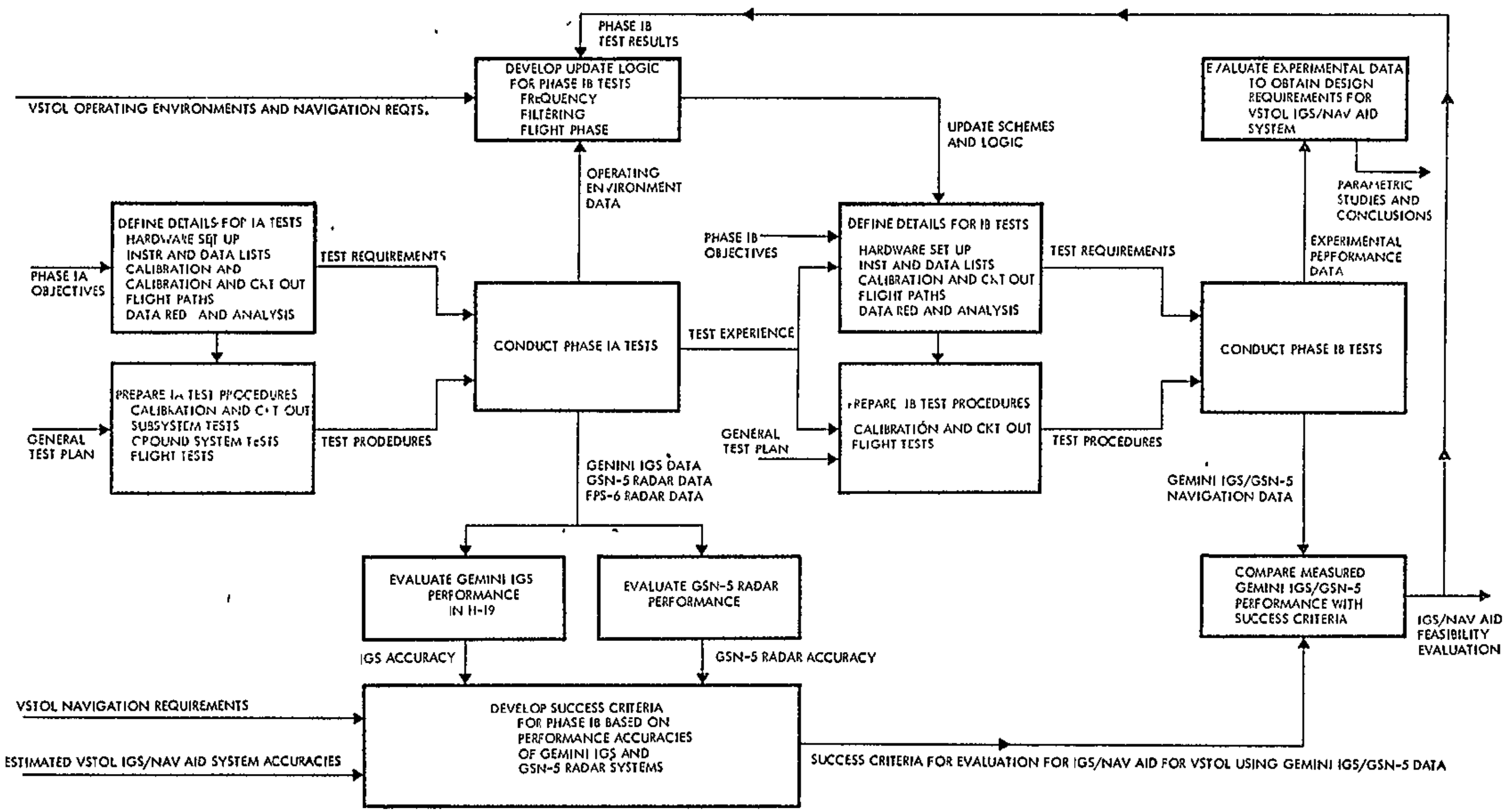

Figure 3-1. H-19 Test and Evaluation Activities

GSN-5 Radar

Gemini Uplink

Gemini IGS

Gemini Downlink

Onboard Instrumentation

- Flight tests to establish the operating limitations and capabilities of the H-19 helicopter for the candidate tests.
- Flight tests to evaluate, individually, the performance capabilities of the Gemini IGS and the GSN-5 radar systems in the helicopter test environment.
- An analysis to develop success criteria based on the performance capabilities of the Gemini IGS and GSN-5 radar systems for evaluating the feasibility of IGS/Nav Aid for V/STOL. (Described later.)
- Tests to check out and calibrate the test and instrumentation systems including:

  IGS Preflight Calibration

  IGS Preflight and Flight Alignment

  GSN-5 Calibration
- Tests and evaluations to evaluate and modify if necessary the onboard and telemetered instrumentation including:

  Telemetry Lists

  Data Rates

  Onboard Recording Capability
- Evaluations to develop improved test conditions and techniques based on Phase 1A experience for conduct of the Phase 1B tests.
- Evaluations to establish realistic parameter variations for the 1B update scheme within the flexibility of the 1B software.

3.3.2 Phase 1B

- Flight tests to evaluate an IGS/Nav Aid system for V/STOL terminal navigation. (Gemini IGS/GSN-5 navigation will be compared with appropriately modified V/STOL requirements.)

- Flight tests to gather experimental performance data from the simulated V/STOL IGS/Nav Aid system as follows:

  Navigation accuracy vs flight phase and geometry

  Navigation accuracy vs vehicle maneuvers

  Navigation accuracy vs weather

  Navigation accuracy vs update frequency

  Navigation accuracy vs update filtering logic

  Navigation accuracy vs update accuracy and characteristics

  Navigation accuracy vs IGS accuracy and initial conditions

  Combinations of the above

3.4 SUCCESS CRITERION

For the purpose of assessing the success of the flight tests and evaluating the feasibility of the concepts being tested, a set of baseline performance goals will be established. The success criterion serves this function and is identified below for the H-19 flight tests.

- The basic flight success will be established by agreement between predicted versus measured performance (within specified tolerances).

These tolerances will gradually be reduced as the tests proceed from the initial model refinement state to more realistic simulated V/STOL conditions.

The above criteria provides a basis for extrapolating the H-19 flight test results and models to the V/STOL applications. In this manner the results of the H-19 program will be effectively used to: a) permit preliminary analysis and synthesis of G&N systems for V/STOL and b) design more realistic flight tests and experiments for the advanced test programs.

In the H-19 program emphasis has been placed on investigating performance variations as a function of flight conditions, time etc., as contrasted with achieving same absolute level of performance. Absolute

performance will of course become of prime importance in the advanced test programs where test equipment more closely resembling that to be used for advanced V/STOL is incorporated into the program.

3.4.1 Test Equipment Applicability

To provide a baseline from which the H-19 test results can be eventually extrapolated, the primary test hardware and its applicability to the V/STOL development program are briefly considered below:

- H-19 Helcopter
  - (1) Provides test bed for simulation of V/STOL environment and flight paths during terminal maneuvers from transition to touchdown.
  - (2) Dynamic environment and flight paths will be grossly comparable with those for V/STOL.
- Gemini IGS
  - (1) Provides inertial measurement unit for the simulated V/STOL IGS/Nav Aid system to be tested.
  - (2) Accuracies of Gemini inertial sensors are considered comparable to those that will eventually be used in production V/STOL IGN/Nav Aid systems. (Sensors with much higher accuracies will be available but are not expected to be required.)
- GSN-5 Radar
  - (1) Provides the source of update data for the simulated V/STOL IGS/Nav Aid system to be tested.
  - (2) The lateral accuracy of GSN-5 data is expected to be grossly comparable with that of V/STOL aid. Altitude information from GSN-5 is several times poorer than that expected from onboard altimeters.
- Gemini Uplink (DCS)
  - (1) Provides the communication link for update data in the simulation V/STOL IGS/Nav Aid system.

(2) Performance of uplink is anticipated to be comparable with the eventual V/STOL uplink.

In addition to the above hardware, the test system will include an update scheme and logic for combining external updates with IGS navigation data during the different phases of V/STOL terminal flight. Various potentially promising schemes will be developed, tested and evaluated in this program. The update criteria established will be directly applicable to the eventual V/STOL IGS/Nav Aid development program.

4. GENERAL SYSTEM DESCRIPTIONS

This section presents a general description of the overall equipment used in the test program. Detailed descriptions of the instrumentation portion are covered in Section 5.

To meet the objectives of Section 3, an experimental navigation system will be used consisting primarily of refurbished inertial navigation, telemetry, and ground support equipment from the Gemini program and a GSN-5 ground radar integrated to provide an experimental aided-inertial system. Both the Phase 1A and Phase 1B experiments will be conducted with one basic system configuration. The system is described with the aid of Figure 4-1. Inertial navigation measurements are provided by the Gemini inertial measurement unit. Simulated radio aid updates are provided by the GSN-5 ground radar position and velocity measurements of the H-19 helicopter. These updates are transmitted to the flight system by the digital command system (uplink). In addition, the GSN-5 radar serves as an independent tracking device (refer to Section 5 for a description of the GSN-5).

The Phase 1A experiments will be conducted using the inertial navigation system. During this same period, the digital command system and GSN-5 radar will be checked out and the navigation update capability verified. The Phase 1B tests will be conducted making use of the GSN-5 uplink and revised 1B software.

4.1 EQUIPMENT BREAKDOWN

The equipment used on the H-19 program is separated into three categories. These are:

- Flight System
- Ground Aid System
- Ground Test System

and are presented in Figure 4-2, 4-3, and 4-4, respectively. A general description and the function of each of the subsystems is provided in the following paragraphs.

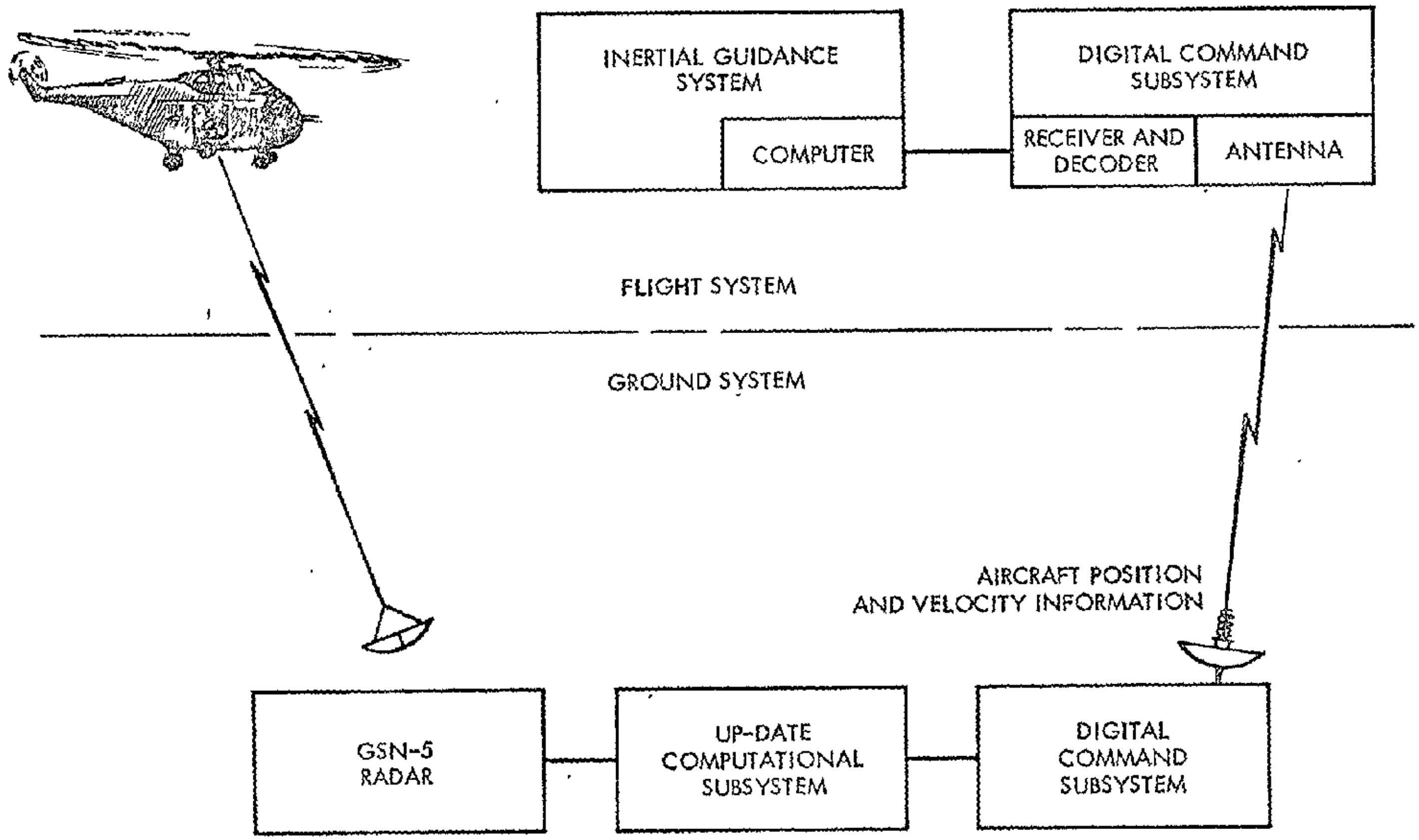

Figure 4-1. H-19 Aided Inertial Navigation System Functional Block Diagram

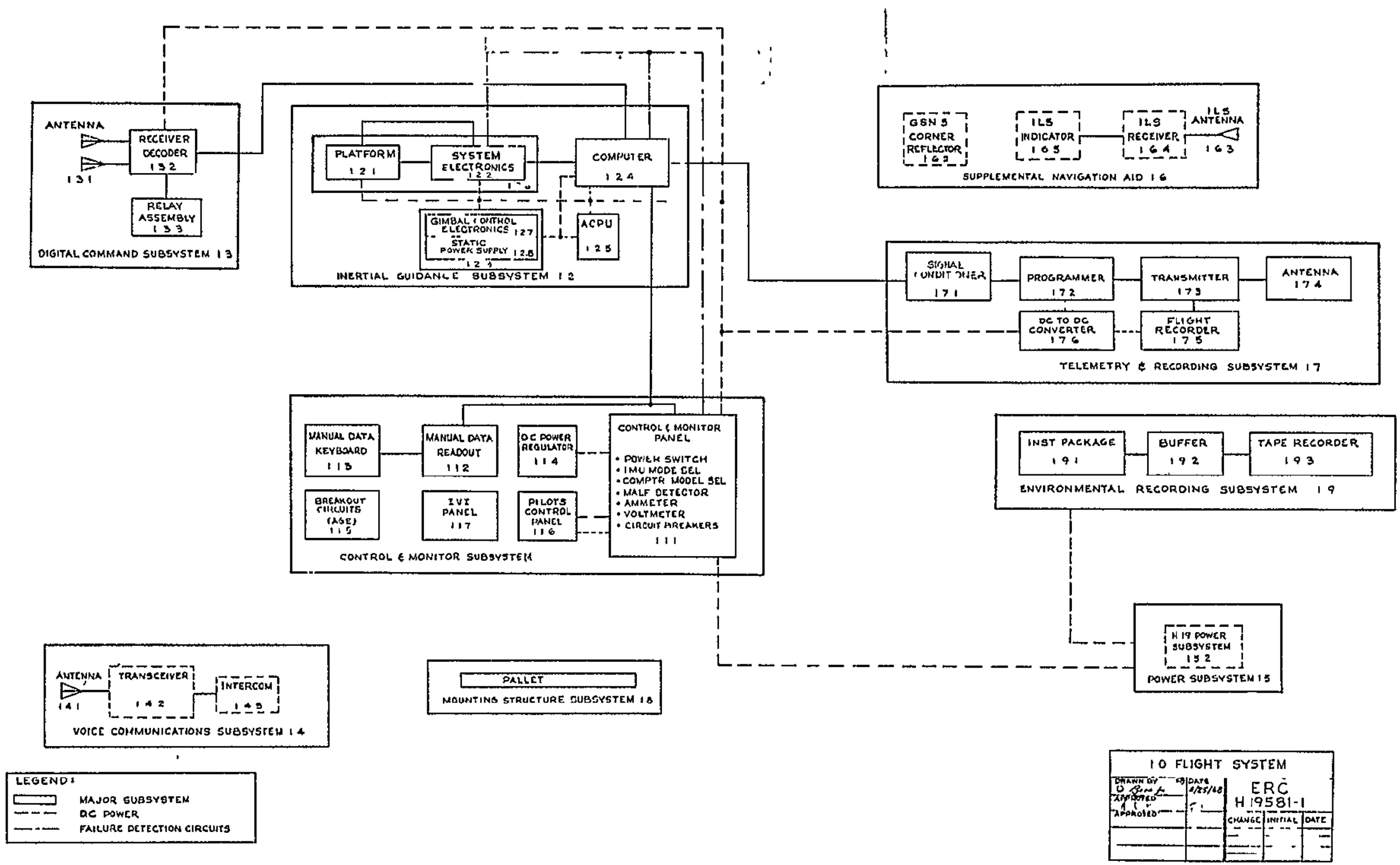

Figure 4-2. Flight System

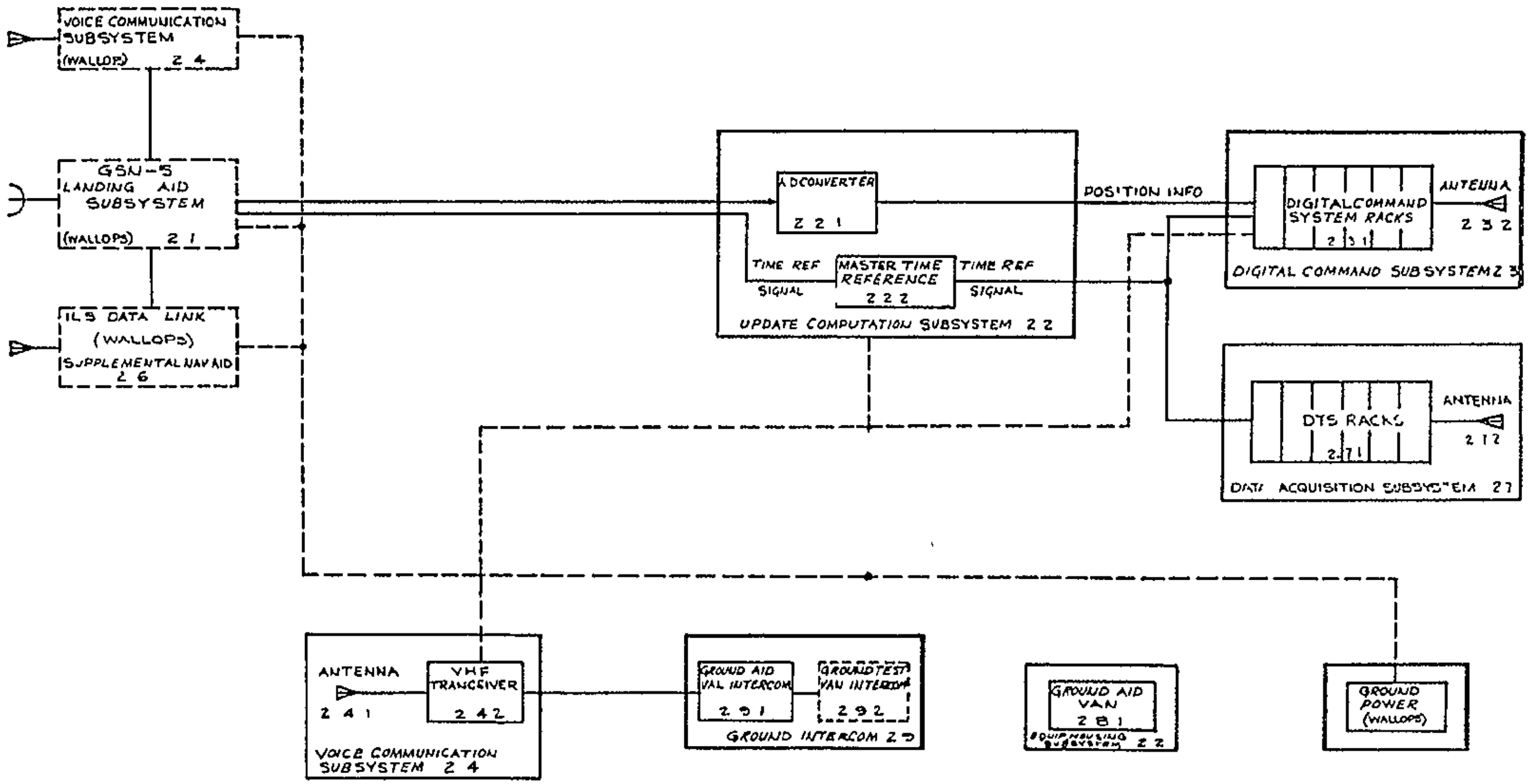

Figure 4-3. Ground Aid System

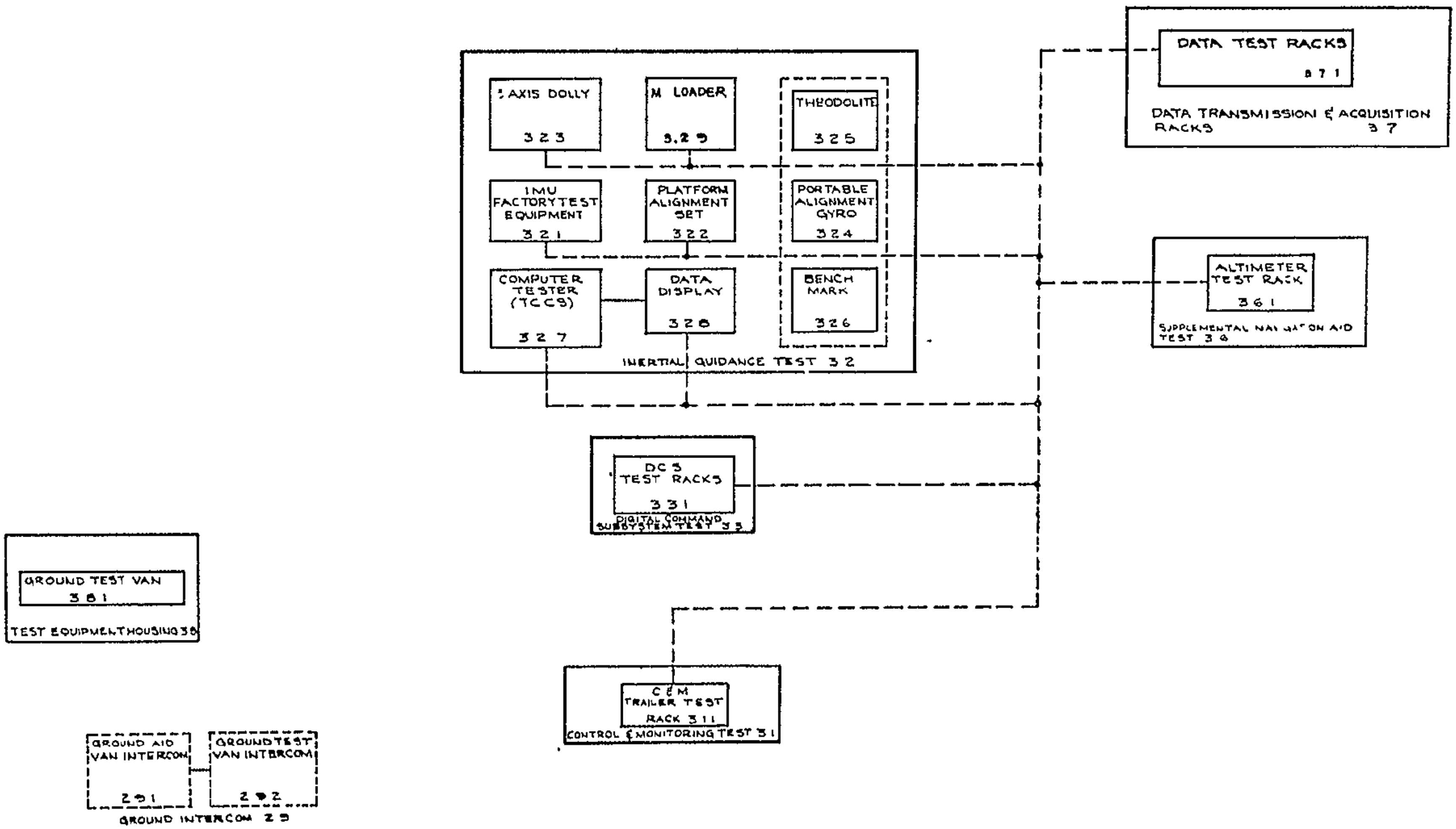

Figure 4-4. Ground Test System

4.1.1 Flight System

The Flight System is composed of the following major subsystems:

- Inertial Guidance System
- Digital Command System
- Control and Monitor
- Telemetry and Recording
- Supplemental Navigation Aids
- Environmental Recording System
- Power System
- Voice Communication
- Equipment Pallet

Inertial Guidance Subsystem:

The Inertial Guidance System (IGS) provides velocity, position, and attitude measurements of the H-19 aircraft. The inertial guidance system consists of the 4 gimbal inertial measurement unit (IMU), computer, power supplies, and electronics. To prevent computer drop out during power transient conditions an Auxilliary Computer Power Unit (ACPU) is provided as a part of the flight system. Control of the IGS is performed by the Control and Monitor Unit described below. The IGS computer will also be utilized in Phase 1B to implement the update logic and filtering to accept position update via the uplink.

Digital Command Subsystem:

The digital command system (DCS) consists of a receiver-decoder and antenna plus associated electronics and provides the link between the ground and the flight system. The primary function of the DCS (airborne portions) will be to provide to the flight system, the GSN-5 radar position information transmitted up the H-19. In addition, the master time reference signal will be sent up the DCS link to the flight recorder. Refer to Section 5 for a detailed description of the DCS.

Control and Monitor Subsystem:

The control and monitor system serves as the control and operator interface point for the inertial guidance system in the aircraft. From the control panel, the operator can activate and de-activate all power to the flight system and monitor parameters considered critical from a system operation point of view. In addition, by the use of the manual data insertion and readout unit the operator will insert into the IGS digital computer final information required prior to flight (i. e., navigation constants instrument compensations, etc.).

Telemetry and Recording:

The telemetry and recording system will be used to provide permanent records of the pertinent data during each test. This system is composed of the following airborne units: programmer, DC to DC converter, flight recorder, antenna and transmitter. The telemetered and recorded parameters are listed in Section 5. The basic parameters are recorded and simultaneously telemetered.

Supplemental Navigation Aids:

The supplemental navigation aids consist of a corner reflector for the GSN-5 ground radar, an ILS system and an altimeter. Present plans do not include the altimeter is a potential navigation aid for future tests. The ILS system will be utilized as a general flight path display to the pilot in executing the flight plans.

Environmental Recording Subsystem:

During the Phase 1A tests, the instrument package will consist of a three-axis crystal wideband accelerometer to monitor the translational vibrations. A more complete self-contained instrumentation package is in the design phase and may be checked out in the later H-19 flights. The design is composed of an instrument package, buffer amplifiers and a tape recorder with the instrument package containing rate gyros, angular and linear accelerometers and electronics. The function of the system is to monitor and record the angular and translational vibration environment near the IGS. This will be accomplished by utilizing rate gyros and angular and linear accelerometers as sensing devices.

Power System:

Conditions the power from the H-19 helicopter and provides as an input to each of the subassemblies in the flight system. Regulations will be provided. Subdistribution to the IGS equipment is provided by the self-regulative Gemini power supply.

Voice Communication:

This system consists of an antenna. transceiver and an intercom and provides the communication link between the aircraft and the ground. Ground to aircraft communication will be provided only between the test conductor and the pilot.

Equipment Pallet:

The equipment pallet serves as the attachment point for all of the sybsystems of the flight system. The pallet will physically interface with an adapter plate in the equipment bay of the H-19. The only electrical interface between the pallet and the H-19 will be the power cable and pilot power control switch, located in the cockpit.

4.2 GROUND AID SYSTEM

The Ground Aid System is composed of the following major subassemblies:

- GSN-5 Ground Radar
- Digital Command Subsystem
- Data Acquisition Subsystem
- Update Computation Subsystem
- Voice Communication Subsystem
- ILS Data Link
- Ground Power -

GSN-5 Ground Radar:

The GSN-5 radar serves two equally important functions. That is, it functions as an independent tracking device and as a link in the aircraft navigation update mechanization. Refer to Section 5 for a detailed description of the GSN-5.

Digital Command Subsystem:

The digital command system (DCS) consists of a receiver-decoder and antenna plus associated electronics and provides the link between the ground and the flight system. The primary function of the DCS will be to interface with the inertial guidance system computer and the GSN-5 ground radar during the navigation updates. In addition, the master time reference signal will be sent up the DCS link to the flight recorder. Refer to Section 5 for a detail description of the DCS.

Data Acquisition Subsystem:

The data acquisition system receives and records the information transmitted from the flight system telemetry unit. Refer to Section 5 for a detailed description of the telemetry and data acquisition system.

Update Computation Subsystem:

The update computation subsystem consists of an A/D converter and the master time reference. The A/D converter is used to convert the GSN-5 ground radar analog data into digital information which is transmitted to the flight computer via the DCS.

Voice Communication Subsystem:

The voice communication subsystem consists of a VHP transceiver and antenna. This system provides the communication link between the H-19 pilot and the test conductor.

ILS Data Link:

This ILS data link is utilized as a supplemental navigation aid. The pilot will utilize the ILS information (displayed in the cockpit) to assist in carrying out the flight test maneuvers.

Ground Power:

The power required for the ground support equipment and the GSN-5 ground radar will be provided from the Wallops Isle main base power system.

4.3 GROUND TEST SYSTEM

The ground test system includes the various test equipment that will be utilized during calibration, alignment and checkout of the flight and

ground aid systems. The major portion of this equipment will consist of refurbished Gemini test equipment. The exact configuration and descrip- of the subsystems is presently being defined. This section will be revised when the subsystem configurations are completed.

5. INSTRUMENTATION

This section describes, to the detail for flight test planning, the basic instrumentation systems to be employed in the H-19 flight tests as indicated functionally in Figure 4-2, 4-3, and 4-4 of the preceding section. The following instrumentation will be utilized:

- Data Transmission System (Gemini Telemetry Unit)
- Airborne Flight Recorder (Telemetry Backup)
- GSN-5 Ground Radar
- Digital Command System (Gemini Uplink)
- Timing

Descriptions of these units and their operations are provided in the following subsections.

5.1 GEMINI DATA TRANSMISSION SYSTEM (DTS)

For the H-19 experiments, this system will employ Gemini vehicle and ground telemetry equipment to establish an H-19/ground link. The Gemini telemetry system is a composite baseband system permitting the transmission of up to 51.2 Kbps of PCM/PSK simultaneously with FM/FM and discretes. The PCM format is NRZ with a frame length of 160 words of 8 bits each.

5.1.1 General Instrumented Parameters

A general list of the computed parameters (a total of 21) to be monitored for both the 1A and 1B phases is provided below:

- Platform Gimbal Angles (pitch, roll, yaw)
- Accelerometer outputs (a_x, a_y, and a_z)
- Timing signals (flight, cycle, integration)
- Latitude, longitude, altitude (earth center)
- Positions in ECI frame
- Velocities in ECI frame
- Heading and flight path

In addition, some 26 indicators have been identified to provide a measure of flight equipment operability. These include such items as:

- Equipment on-off indications
- Equipment malfunction signals
- Critical power and voltage levels
- Receiver strength signals

All telemetry transmission will be recorded in the H-19 (see Section 5.2) and at the ground terminal in serial form. A quick readout capability is provided at the ground terminal. The DTS also provides a verification pulse for commands received over the Gemini digital command system (DCS) as explained in Section 5.4. The Gemini airborne computer has a major cycle time of 2.4 seconds, so the data rate of each of the previously listed parameters to be telemetered will be approximately .4/sec.

5.2 AIRBORNE FLIGHT RECORDER

The purpose of this device is to serve as backup to the H-19/ground telemetry link. It will record all down link transmissions in serial record form, and will be compatible with the down link programmer. The DTS terminal (ground) equipment has the capability for rapid readout of recorded TM data and will permit readout of the tapes from the flight recorder. The flight recorder will have a four hour recording time, permitting several missions to be run without tape replacement.

5.3 GSN-5 RADAR DESCRIPTION

The GSN-5 is a 33 KMC conical scan, automatic tracking radar capable of operating against either echo or beacon targets. A corner reflector will be employed for the H-19 experiments. The pertinent characteristics of the GSN-5 are given below:

Peak transmitter power	40 KW
PRF	2000/sec
Pulse Width	.2 μsec
Average transmitter power	16 watts

Antenna	4 ft Paraboloid
Angenna gain	49 db
Half power beamwidth	$.5^{\circ}$
Nutation rate	60/sec
Maximum angular coverage	$\pm 45^{\circ}$ azimuth -10° to 30° elevation

A simplified block diagram of the GSN-5 landing/control system is shown in Figure 5-1. Aircraft position is determined from the range, azimuth and elevation measurements of the radar. This polar information is then transformed and differentiated to obtain $\dot{X}$, $\dot{Y}$, $\dot{Z}$. X, Y, and Z are processed through the slope deviation computer, which compares the coordinates with the desired glide slope and determines deviations from the slope.

Data outputs at the radar consist of range versus lateral and range versus altitude plots. In addition, an 8 channel Sandborn strip chart recorder is provided for recording range, range rate, altitude and altitude rate, altitude error and error rate, pitch command, lateral and lateral rate, bank command and timing. Any 8 of these parameters may be recorded simultaneously.

It should be emphasized that the GSN-5 is a completely analog device; no digital processing of data is done anywhere in the system. Certain tests on the GSN-5 have been identified as outlined in Section 6. The accuracies of the radar as stated by Bell Aerosystems personnel at Wallops Island constitute the best known estimate of GSN-5 accuracy and are listed below.

Function	Maximum Error	Typical Error
X	15 ft or 1% whichever greater	10 ft or 1/2% whichever greater
Y	15 ft or 1% whichever greater	10 ft or 1/2% whichever greater
Z	1 ft or 1% whichever greater	1/2 ft or 1/2% whichever greater
$\dot{X}$	10%	None specified
$\dot{Y}$	10%	None specified
$\dot{Z}$	10%	None specified

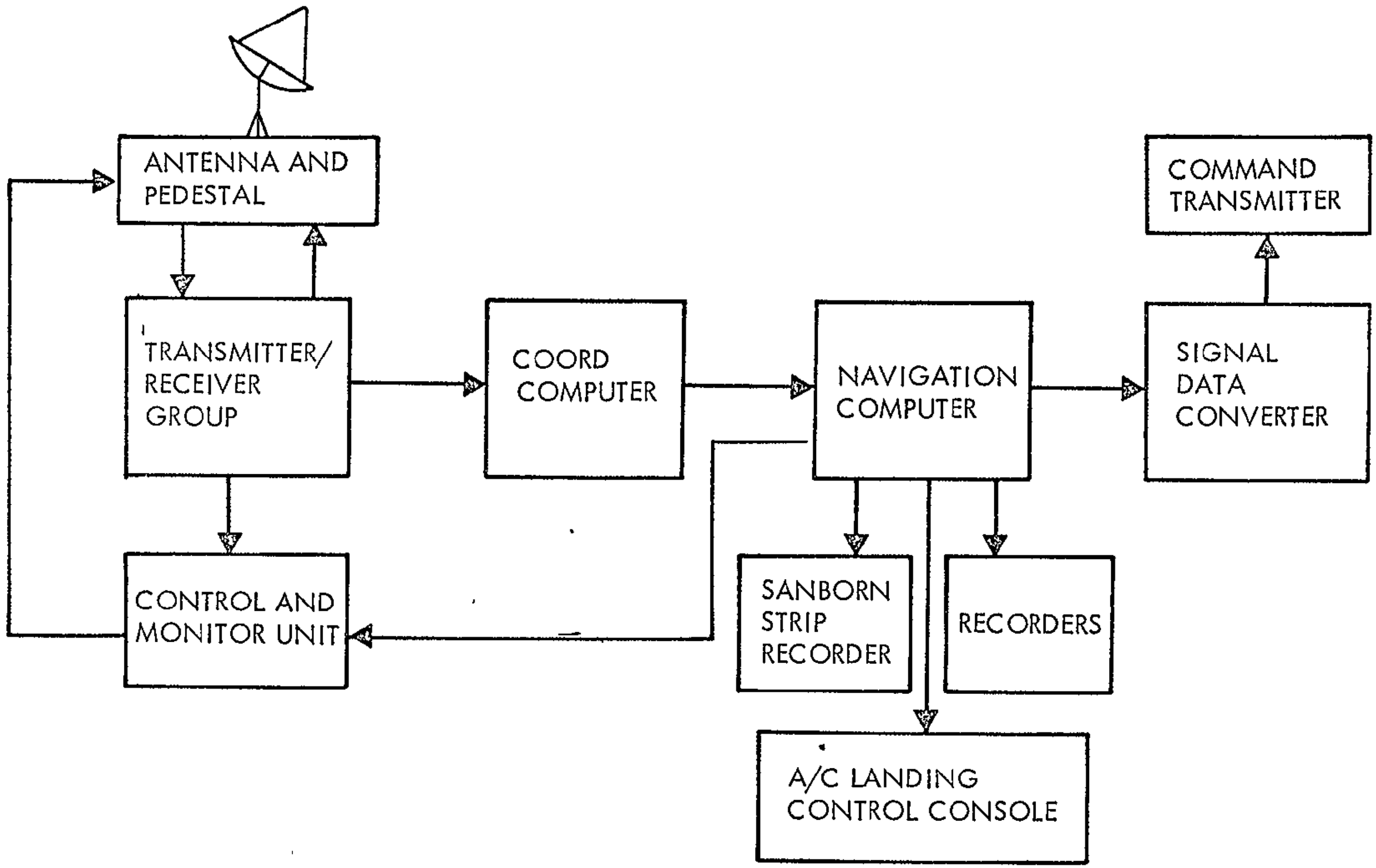

Figure 5-1. GSN-5 Simplified Block Diagram

From examination of GSN-5 data on one operation against a target with unknown characteristics, one sigma thermal noise components of about 4 ft in Y and Z, 5 ft/sec in $\dot{X}$ and 10 ft/sec in $\dot{Z}$ were observed.

5.4 DIGITAL COMMAND SYSTEM (DCS)

The DCS contains the equipment necessary to process and encode data to modulate a suitable transmitter. The basic DCS transmits serial PCM data at a maximum rate of 200 bps. Each bit is encoded to a level of 5 sub-bits, for a sub-bit rate of 1 KC. The maximum bit rate can be increased by modifying the coding. Pertinent features of the DCS are listed as follows:

Prime Operating Modes:
- Input
- Display
- Transmit
- Test

Input
- Teletype (serial)
- Hi-speed (serial or parallel)*
- Manual (parallel)
- Computer (parallel)

Memory Capacity:
- 512 40 bit words

Transmissions:
- Command address select
- Auto
- Auto-select
- Manual

A simplified block diagram of the DCS is shown in Figure 5-2. A 30 watt transmitter with a nominal gain antenna (a helix with 12 to 20 db gain) will be employed for the H-19 experiments.

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*Logic modified to permit parallel high speed input for H-19 experiments.

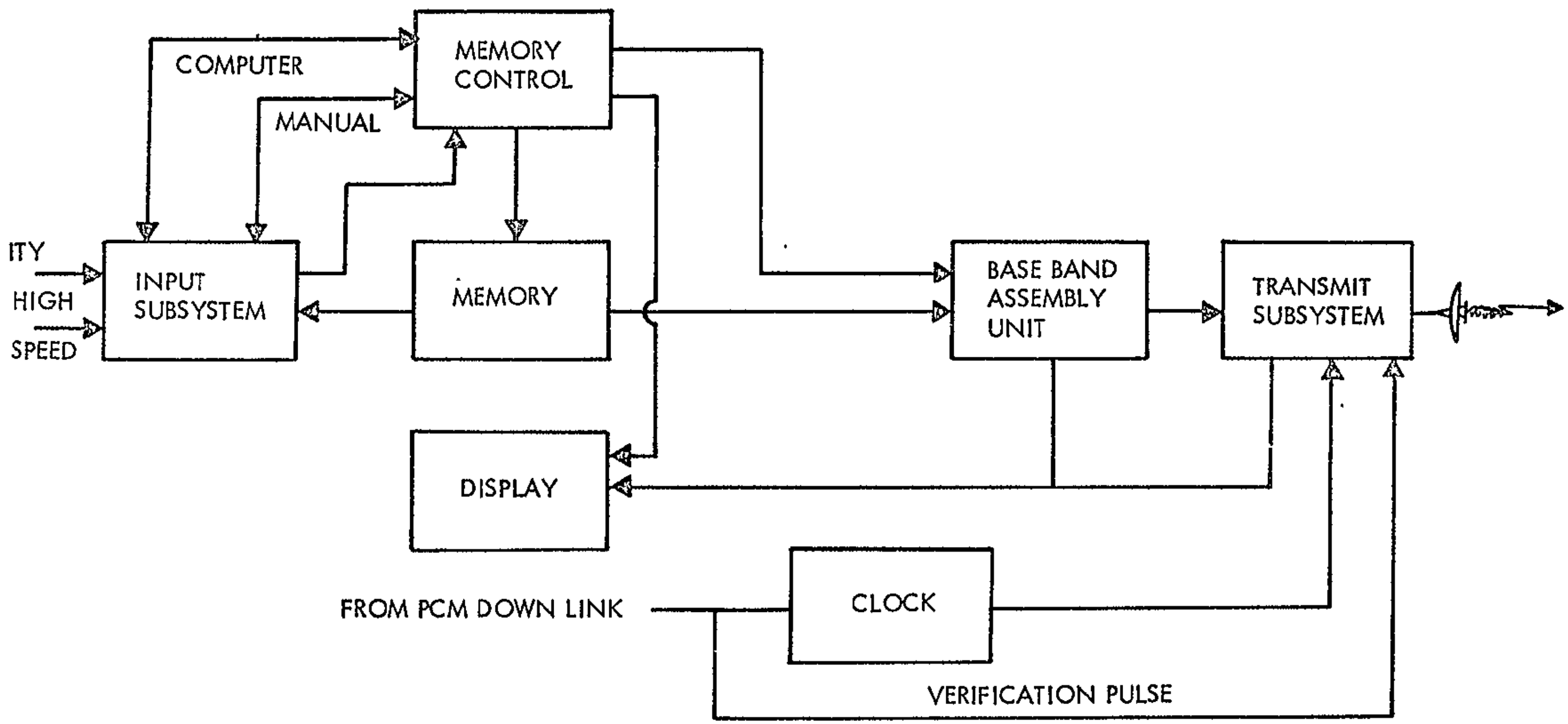

Figure 5-2. DCS Simplified Block Diagram

The memory control unit shown in Figure 5.2 inputs and extracts information from the core memory. The clock subsystem is more or less unique to the Gemini mission, and will not be used to transmit range time for recording on the H-19. Note that the PCM downlink (telemetry) provides a "valid word received" verification pulse that informs the DCS that transmitted commands have been successfully received/decoded.

The DCS is a highly flexible system and the manner in which it is employed in the H-19 experiments will be a function of the experiment objectives rather than any limitations in DCS capability. Since the primary function of the DCS will be to transmit digitized outputs of the GSN-5 to the H-19 for purposes of IMU position and velocity updating, the primary area of interest relative to use of the DCS is the DCS/GSN-5 interface. An A to D converter must be provided to digitize the GSN-5 radar outputs for input to the DCS as well as for recording for postflight data processing.

A Raytheon 14 bit word, 16 KC/channel A to D converter will be provided and can output either serial or parallel data or both. The serial output of the converter will be hand wired to the DTS van for recording, and simultaneously, a parallel output will be piped to the DCS high speed input. If the auto transmit mode is selected, the DCS then can be programmed to transmit X, Y, Z, $\dot{X}$, $\dot{Y}$, $\dot{Z}$ and range time or combinations of these parameters at any desired update frequency up to the capacity of the uplink.

5.5 TIMING

A block diagram of the timing scheme expected to be used for the H-19 experiments is shown in Figure 5-3. As shown, 2 timing codes will be employed. The "slow code" (1 pps) which is currently available at the GSN-5 will continue to be used as a coarse time reference for analysis of events recorded on the Sanborn unit. The digitized radar outputs (from the A to D converter) will be time tagged in the DTS by recording the NASA 36 bit 100 pps code available at Wallops on the same tape as the GSN-5 data. The telemetered information from the H-19 will also be ground time tagged in this manner. The airborne time reference will be the computer clock, which will begin counting upon mode selection and output a clock pulse every 2.4 sec thereafter. Since these clock pulses will be telemetered and recorded on the same tape as range time, ground

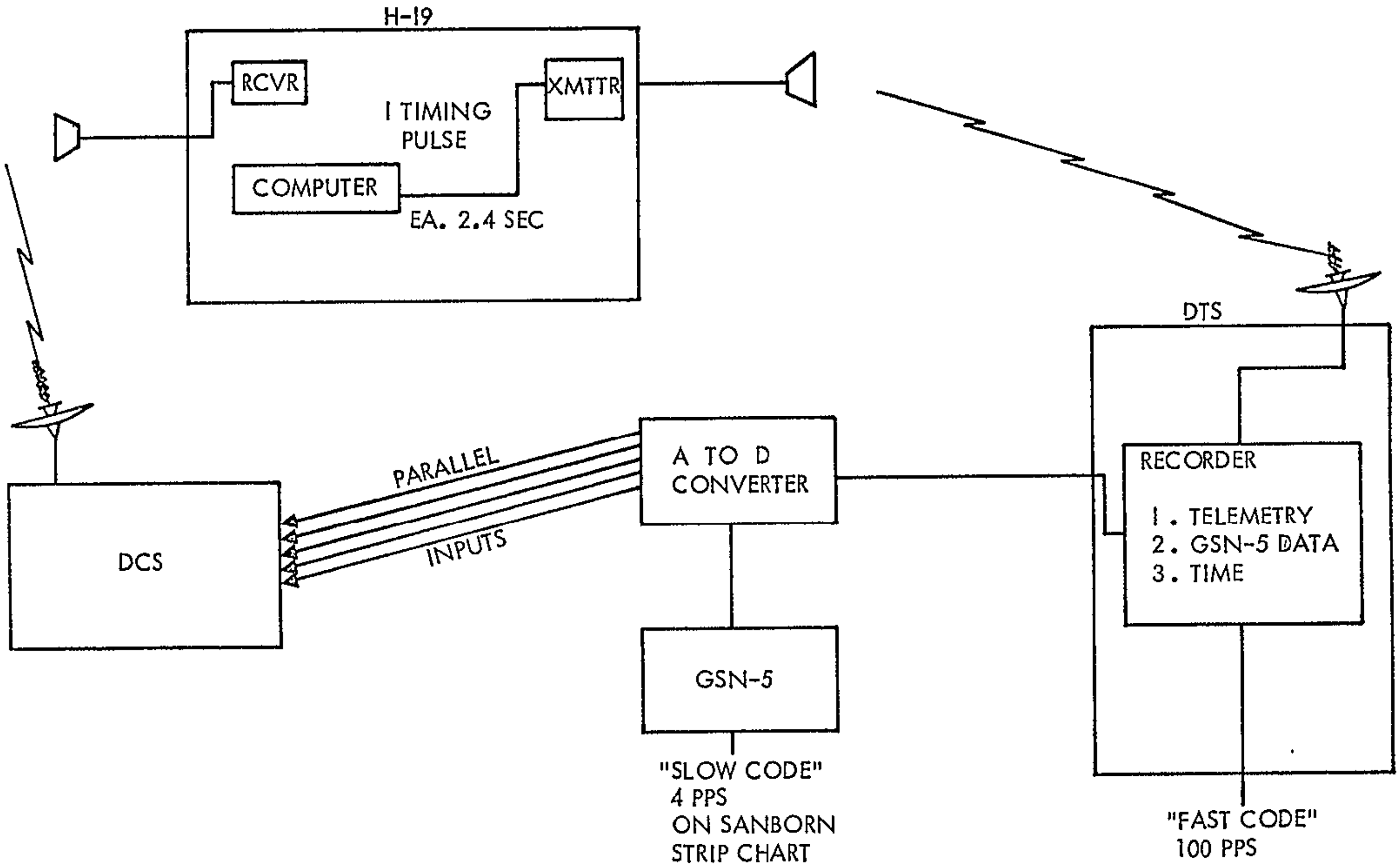

Figure 5-3. Timing Scheme for H-19 Experiments

system/vehicle system time synchronization and the identification of vehicle timing offsets or drifts will be a relatively simple matter in post flight. With this scheme, no timing information is transmitted via the uplink. It should be mentioned that the time from actual measurement of vehicle position by the GSN-5 until the digitized information is passed to the DCS, transmitted to the vehicle and entered into the computer for update purposes should be measured, as a large unknown delay in this process could significantly affect update accuracies.

6. TEST PROGRAM DESCRIPTION

This section describes the Phase 1A and 1B test program to meet the objectives defined in Section 3, using the equipment described in Section 4 and instrumentation called out in Section 5.

6.1 OVERALL TEST FLOW

The relationship between the H-19 flight tests and the related activities are shown in the flow diagram of Figure 6-1. Following laboratory checkout, operability and preflight tests will be performed. Operability checks will initially be performed in checking out the system and periodically thereafter to insure system operability. The remaining blocks in the diagram will normally be cycled through. Quick look analysis will generally be performed after each flight as a basis for conducting the next test. Post-flight analysis will generally be performed after a group of flight tests.

6.2 PHASE 1A TEST SUMMARY

The following lists the categories of tests that will be performed during the Phase 1A test program as shown in Figure 6-1.

- Subsystem Hangar/Field Tests

  1) Receiving and Inspection Tests of the Gemini IGS, Uplink and Downlink Equipment

  2) Periodic Calibration of the Gemini IGS to Measure Performance Parameters Including:

     Accelerometer Biases

     Gyro Biases

     Accelerometer Scale Factors

     Component Misalignments

  3) Calibration and Checkout of the Gemini Downlink Telemetry

- Combined Systems Preflight Tests

  1) Operational Checkout of Gemini IGS, Uplink and Downlink in H-19 Helicopter

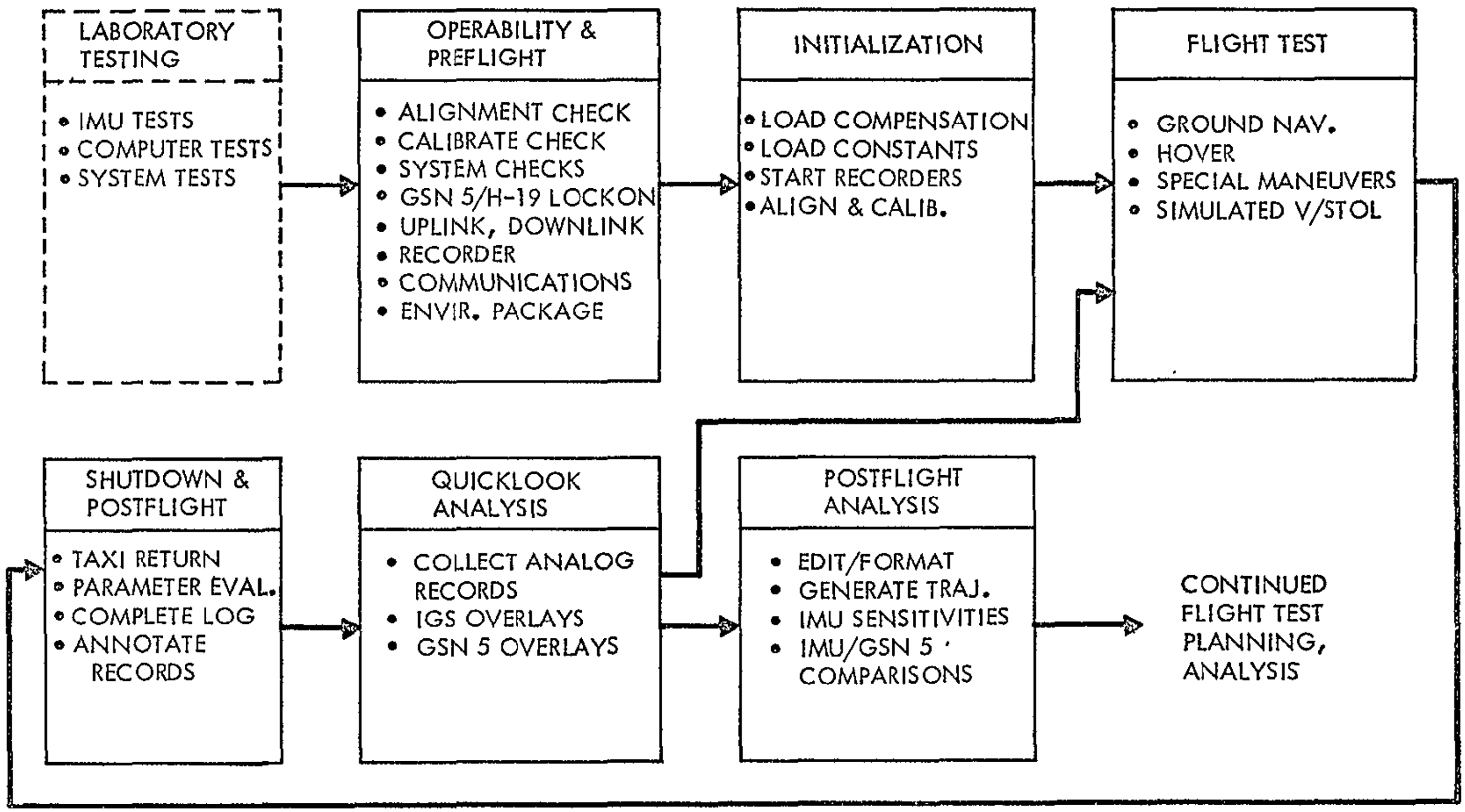

Figure 6-1. A Test Flow

2) Calibration of Gemini IGS in H-19 Helicopter

3) Alignment of Gemini IGS in H-19 Helicopter

- Radar Calibration and Checkout Tests

1) GSN-5 Calibration and Zero Set

- Systems Shake-Down Flight Tests

1) Operational Verification of All Systems During Hover

2) Operational Verification of All Systems During Flight Maneuvers

- H-19 Operability Flight Tests

1) Measurement of H-19 Vibration, Temperature, and Other Operating Environments

2) Measurement of H-19 Hover and Touchdown Capabilities and Limitations

3) Measurement of H-19 V/STOL Simulated Flight Capabilities and Limitations

- Gemini IGS Performance Evaluation Flight Tests

1) Ground Navigation Tests

2) Hover Over Surveyed Location

3) Field Proximity Straight Flight and Maneuvers

4) Level Flight Cruise Simulation

5) Terminal Area Entry Update

- GSN-5 Radar Performance Evaluation Flight Tests

1) Hover Over Surveyed Location

2) Special Maneuvers for GSN-5 Error Measurement and Error Source Separation if Feasible

3) V/STOL Simulated Flight Paths

Procedures will be prepared for each of the above identified tests. The schedule for conduct of the tests is identified in Section 10.0.

6.3 PHASE 1A FLIGHT TEST ANALYSIS OUTPUT SUMMARY

The following is a summary of the analysis outputs that will be generated using the test data developed in Phase 1A:

- A history of IGS calibration data and conclusions regarding expected system performance
- A history of downlink telemetry calibrations in suitable format for use in analyzing system performance from downlink test data
- An analysis of the Gemini IGS ground alignment method including recommended practices and expected accuracies
- A log of IGS performance history and failures
- Requirements for calibration and checkout of the GSN-5 radar prior to H-19 flight tests
- An analysis of the H-19 operating environment
- An analysis of H-19 operational capabilities and limitations including a definition of its capability to simulate V/STOL
- An evaluation of the performance accuracy of the GSN-5 radar and its applicability for simulation of V/STOL
- Development of success criteria for evaluation of IGS/Nav Aid feasibility in the Phase 1B test program
- Recommendations based on Phase 1A test experience for use in designing the Phase 1B test program:

  Instrumentation Requirements

  Telemetry Lists

  Calibration and Checkout Methods

  Alignment Methods

  Test Procedures

  Data Reduction and Analysis
- An analysis and definition of the update logic to be used in the Phase 1B test program

Procedures will be prepared for each of the above identified tasks. The schedule for conduct of the tests is identified in Section 10. 0.

6. 5 PHASE 1B ANALYSIS OUTPUT SUMMARY

The following is a summary of the analysis outputs that will be generated using the test data developed in Phase 1B:

- A continuing record of IGS calibration data and conclusions at end of program
- A continuing history of downlink telemetry calibrations for use in the data analysis
- A continuing log of IGS performance history and failures
- An evaluation of the feasibility of using an IGS/Nav Aid system for V/STOL terminal navigation
- Parametric plots of Gemini IGS/GSN-5 radar navigation accuracy as a function of V/STOL parameters and an analysis of their application to the development of design parameters for a V/STOL IGS/Nav Aid system

6. 6 FLIGHT PROFILES AND TESTS

This section summarizes the nominal profiles and tests to be performed during Phases 1A and 1B.

6. 6. 1 Profile Definition

The nominal profiles for flight testing are given in Table 6-1. Each test has been designed to study a specific aspect of the H-19 system's performance in relation to an actual V/STOL system or condition. The profiles are pictorially represented in Figures 6-2 through 6-5. Within each major test calssification, significant variation in update frequencies, flight times and other parameters can be made to emphasize particular elements of the system's performance which become apparent early in the test program. The profiles are designed to maximize the GSN-5 tracking coverage during periods of critical measurement intervals or updates; since only a 90° azimuth coverage is obtainable with the GSN-5 (a ten-minute reset to another quadrant is possible) some shorter portions of the flight near takeoff may not be tracked.

6.4 PHASE 1B TEST SUMMARY

The following lists the categories of tests that will be performed during the Phase 1B test program:

- Subsystem Hangar Tests

  1) Periodic calibration of the Gemini IGS

  2) Periodic calibration of downlink telemetry

- Combined Systems Preflight Tests

  1) Calibration of IGS in H-19 helicopter

  2) Alignment of IGS in H-19 helicopter

  3) Checkout of uplink/update system

- Radar Calibration and Checkout Tests

  1) GSN-5 Calibration and Zero Set

- Uplink/Update Systems Shakedown Flight Tests

  Operational verification of uplink and update logic in H-19 flight environment

- IGS/Nav Aid Feasibility Flight Tests

  1) Operational tests of Gemini IGS/GSN-5 radar system on simulated V/STOL trajectories using various update schemes

- IGS/Nav Aid Experimental Data Tests, Measurement of Navigation Accuracy

  1) Versus simulated V/STOL flight phase and geometry

  2) Versus vehicle dynamics

  3) Versus weather and time of day

  4) Versus update frequency

  5) Versus update filtering logic

  6) Versus update accuracy and characteristics

  7) Versus IGS accuracy and initial conditions

Table 6-1. Nominal Flight Test Profiles

Test No.	Type	Flight Profile	Function	Total Flight Time	Updates	GSN Performance
1.	Ground Navigation	H-19 operate IMU while on the ground at the landing site. Sub-conditions are: a) Rotor off b) Rotor turning. Performance of IMU is monitored for 15-20 min. period	a) Checkout the onboard performance of the equipment in the H-19 b) Confirm telemetry and uplink operation in presence of H-19 mechanical and electrical environment c) Isolate the ground nav. performance due to H-19 vibration environment--compare and use vibration package data. Compare results with lab tests	10' - 15'	None except to provide checkout of uplink operation	Not used
2.	Hover	A. H-19 hovers at 10' altitude while pilot maintains position on gyro B. Hover, with rotation around H-19 vertical axis	A. 1. Determine IMU operation in hover, vibrating high power environment 2. Evaluate vibration package outputs B. Check IMU stability in presence of large yaw rates	10' - 15'	No, except to provide checkout of uplink operation	GSN may be tested here to compare short range performance with known H-19 location GSN at direction of hover point
3.	Field Proximity Straight Flight and Maneuver	A. 1. Liftoff into wind (east) climb 400 Fpm to 400' at 30 mph ground speed--right turn to parallel runway 10 at end of runway climb to 800' and fly straight/level to end of 10--right turn into easterly flight parallel to 10 2. 1000' from GSN-5 right turn across runway repeat race course pattern 3. Final leg begin descent on glide slope on entry into final leg - land B Add oscillatory side-to-side H-19 motion during legs	A 1. Test IMU performance in flight while near field 2 Test IMU performance during terminal descent entry in area of good position location 3 Test GSN-5 error model while flying near known check points B Force high frequency flight-dependent errors in the IMU	5' - 20'	a) Test update at terminal descent entry b) Test IMU error propagation as function of update interval	Max range 8000' Accuracy should be on order of 20-30' Velocity accuracy determination may be tested here for later phase 1B update planning GSN beam zero azimuth at 280°

Table 6-1. Nominal Flight Test Profiles (continued)

Test No.	Type	Flight Profile	Function	Total Flight Time	Updates	GSN Performance
4.	Level Flight Cruise - Long range update accuracy prediction	1. Liftoff into wind (if east, make right turn over GSN-5) parallel runway heading in southern direction 400 Fpm rate of climb, 40 mph ground speed-maintain for 5 min. - level out at 2,000 feet - fly 60 mph for 3 minutes until reaching FPQ-6 or SPANDAR radar site (requires clear visibility) mark overflight of radar by hand entry - Left turn at 2000', fly east to coastline (2 min) left turn return to field at west end of 28 runway, right turn and descent along slope to landing point.	A. Evaluate the IMU performance during sustained climb and level flight periods of the H-19 B. Provide data on larger range tracking capability of the GSN-5	20 - 25'	Update at glide slope entry to remove accumulated 15' error history	GSN max range reaches 7 miles evaluation of its updating capability mode during the mode GSN beam zero azimuth at 220°.
5.	Terminal Area Entry Update	Liftoff - Fly 5 miles northeast of field climbing to 2000 feet - make 180° turn return parallel to runway at 2000 feet. Fly 6 miles from field to SPANDAR site - make shallow turn 180° to return to field - begin 6° letdown 3 miles from field - land	a) Simulate an advanced system update of a cruise to terminal area entry by GSN 5 update as H-19 passes GSN-5 after first leg (10 min of flight). b) Evaluate accuracy of system following terminal area update by successive updating during landing approach	25'	1. Simulated terminal area entry with higher accuracy than GSN-5 would produce at long ramp (20 miles) accomplished by "folded" flight path update at first close passage with 25-50' accuracy 2. 2nd update sequence at initiation of glide slope at 3 mile point	25 - 50' at first update for simulated terminal area entry 50 - 100' for inertial update at glide entry improving to 10 - 20' for final update. GSN beam zero azimuth at 220°.

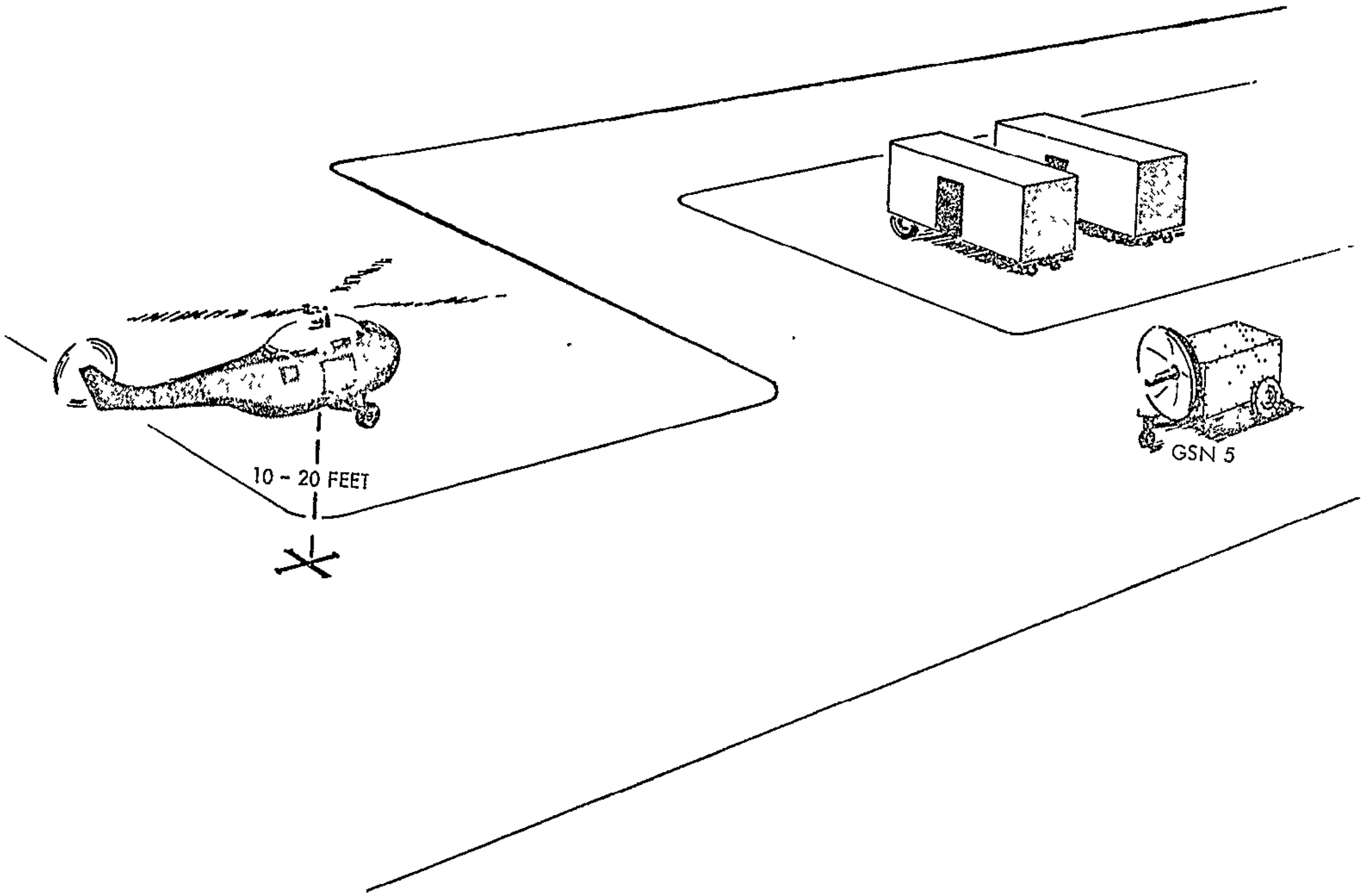

Figure 6-2. Profile 1 and 2 Ground and Hover Navigation

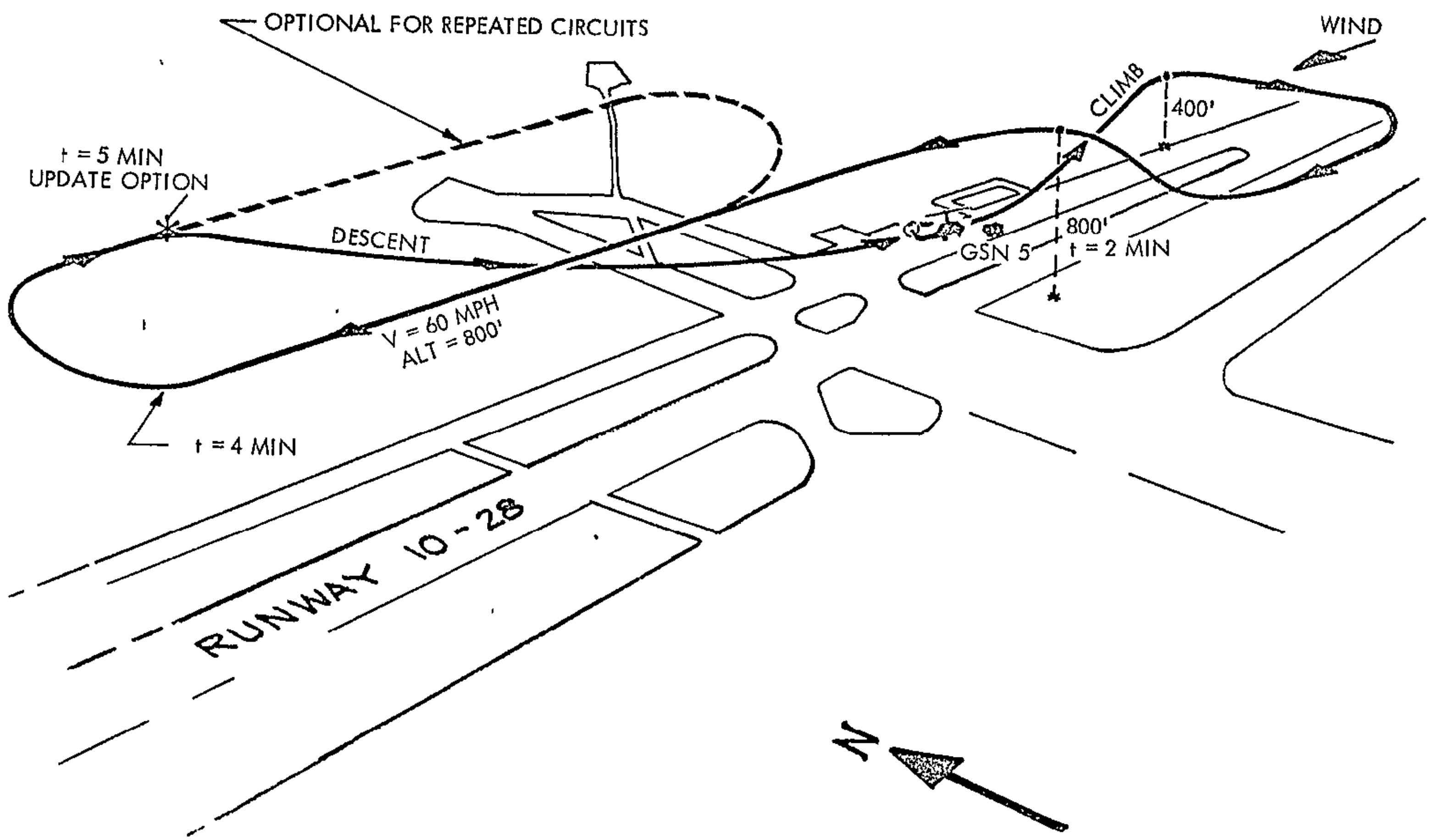

Figure 6-3. Profile No. 3 Field Proximity

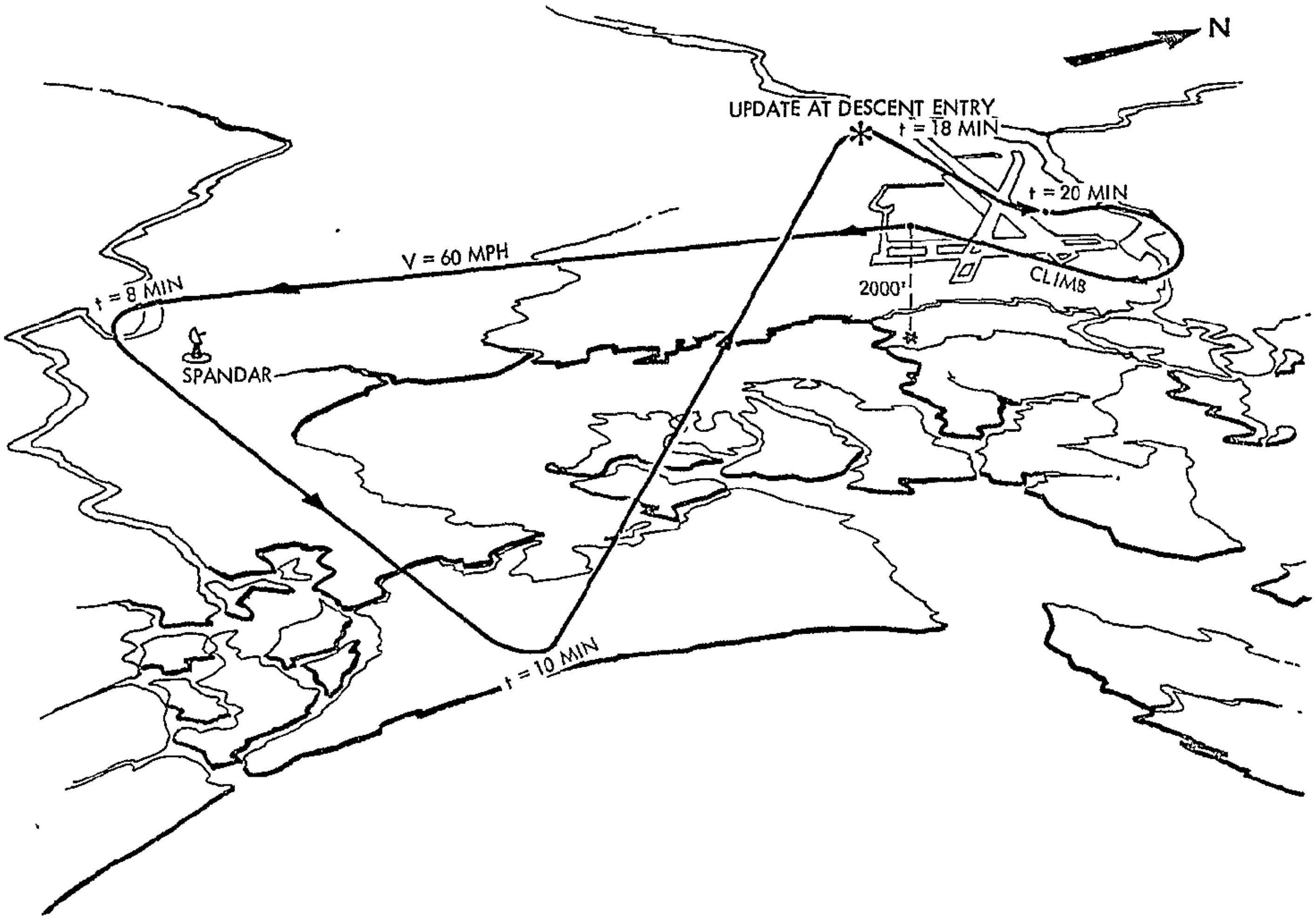

Figure 6-4. Profile No. 4 Level Flight Cruise

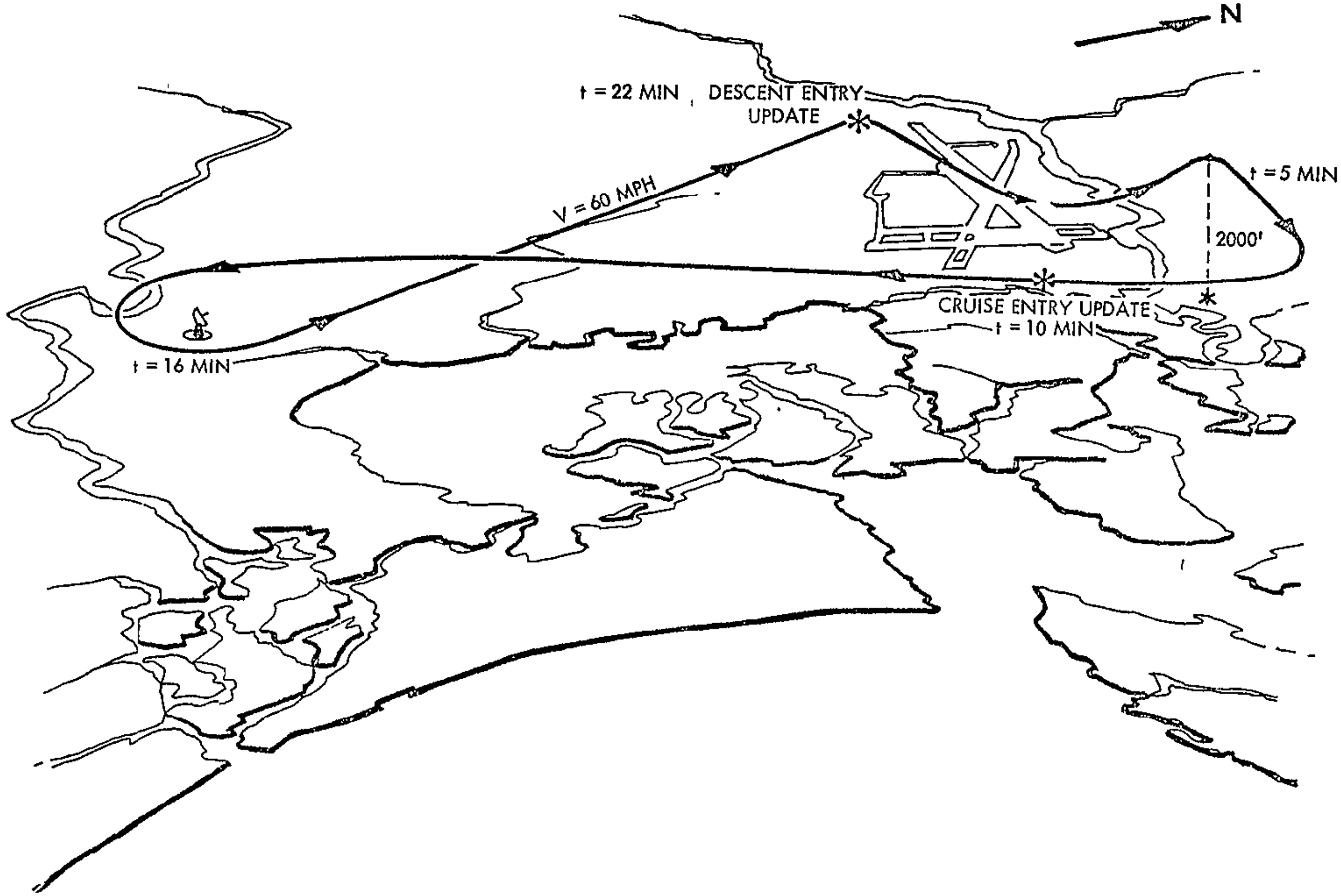

Figure 6-5. Profile No. 5 Cruise Entry Update

6.6.2 Profile Development

Preliminary flight profiles developed for the H-19 are designed to provide in-flight measurement of aided inertial performance required to meet the test objectives. The profiles that have been developed emphasize different flight profiles designed to isolate inertial only and update inertial system errors, and to provide data representative of V/STOL mission plans. Note that actual V/STOL flight profile simulation is not an objective, but the profiles representative in an error generation sense of these profiles are designed within the constraints of the H-19 helicopter, the Gemini IMU, and the GSN-5 updating and tracking system.

The test profiles recommended are general enough to permit adjustments to accommodate special restrictions on flight areas at Wallops Station if necessary.

The flight profiles defined are subject to the following considerations and restrictions:

H-19

- Duration of Flight — less than 30 min.
- Rate of climb limitation — 500 fpm
- Max horizontal speed — 100 fps
- Wind — must takeoff and land into wind if over 10 knots
- Safety — flight must conform to normal flight safety standards with respect to terrain clearances and weather
- Maneuvering — maneuvers must be within the safe flight limits of the H-19

GSN-5

- Accuracy — of 10' bias plus .7 percent of the range, and 1 mil angular, are anticipated for the GSN-5. Locations of tracking and updating must be picked with these position-dependent errors considered

- Elevation angle — sufficient elevation angle to maintain track in the required zones must be maintained: obstruction to low elevation tracking must be noted (buildings, trees)

- Range limitation — the maximum effective range of the GSN-5 is about 15 miles (with corner reflector)

- Slewing rates — the GSN-5 can slew at about 16^{o}/sec

- Angle coverage — $\pm 45^{o}$ azimuth - 10 to 30^{o} elevation

- Weather — the performance (range) of the GSN-5 is likely to be somewhat degraded in the presence of rain or snow

Figure 6-6 shows the air field with the preferred GSN-5 coverage sketched in. Two primary azimuths are desired to cover the proposed tests.

6.6.3 Detailed Flight Test Description

Table 6-1, containing the baseline flight test profiles, organizes the total flight test design, apart from functional checkout flights, around five separate profiles; a number of tests are included, each with separate objectives but grouped logically to make use of a particular profile. Table 6-1 contains a description of the function of the tests; further discussion of specific test procedures and objectives is provided below:

Type 1 Profile - Ground Navigation

Test 1

Checkout and evaluation of system performance in H-19 installation. This test will confirm operation of the IMU and associated electronics with H-19 power plant on (rotor turning) and off. Successful test results will be evidence of readiness to proceed to flight status with the IMU.

Test 2

Confirm uplink/downlink operation — With the H-19 on the ground, with the engine on, the data link system will be tested to assure the system operational capability in the presence of H-19 electrical and vibratory environment.

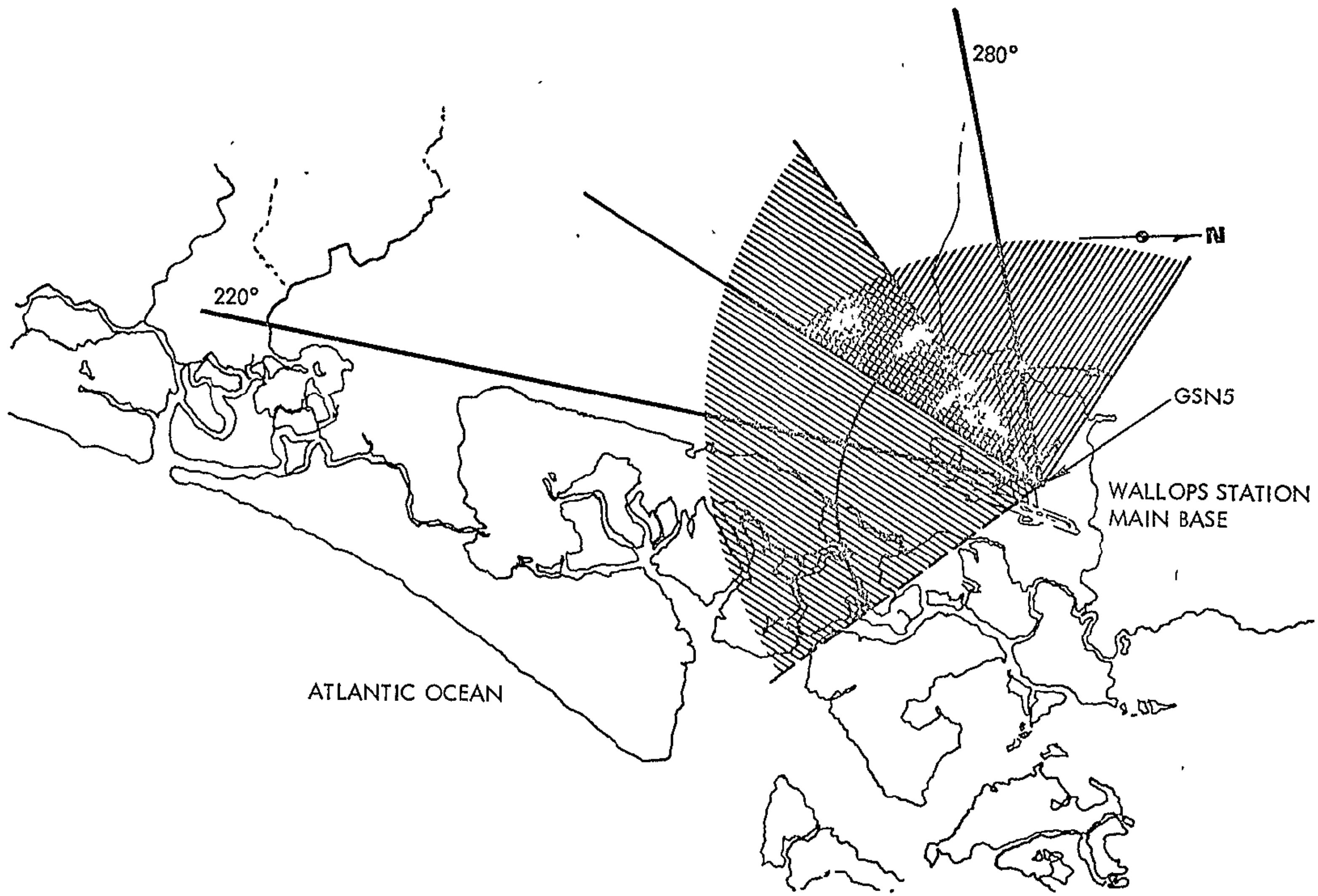

Figure 6-6. GSN-5 Radar Coverage

Test 3

Ground Navigation — This test will concentrate on studying the accuracy of the IMU in a pure inertial mode while the H-19 position is known (on the ground). The downlink telemetry and onboard recorder data for this test can be compared to confirm consistent data, and total IMU error evaluated versus time. The data evaluation techniques will be exercised on this test to determine the accuracy and feasibility of recovering specific IMU errors from the data. Based on a number of these tests, statistical properties of the IMU in the H-19 power-on environment will be compiled and used to modify the predicted performance in the flight environment.

Type 2 Profile - Hover

Test 1

Evaluation of IMU accuracy in hovering flight — The hover tests will confirm the operation of the IMU under a H-19 environment which may be expected to generate maximum levels of vibration, since hovering flight requires high power. The hover flight will first feature essentially zero turning, while maintaining position over a well-located position. The outputs of the vibration package will also be evaluated during these tests and correlated with IMU output. The up-link operation may be checked out during this test to prepare for Phase 1B testing.

Test 2

This test will also require hovering over a known location, but will include yawing, or rotation, at the highest rates characteristic of rapid turns in the flight environment. Results from these hover flight tests will be examined and compared to the static ground navigation IMU results to validate the IMU model and compile statistical data on the IMU performance in the flight environment. Data evaluation procedures will be tested again to examine error model term recoveries, and sensitivities to the hovering flight profile.

Type 3 - Field Proximity

Test 1

The purposes of this test are to determine IMU performance in straight and level, climbing, and turning flight while in a region of high GSN-5 accuracy. The IMU error trends will be evaluated as a function of

flight profile segments. In addition, Phase 1B tests involving descent entry updating will be made under this profile to evaluate the aided inertial system performance parameters in final descent path operation.

Extended flight times for this profile may be generated, as shown in the sketch (Figure 6-3) by making repeated circuits of the basic profile pattern.

Test 2

Any sensitivity of the IMU to the highest natural flight maneuver frequency of the H-19 will be evaluated by superimposing in profile 3 an oscillatory side to side (coordinated roll-raw) motion during the "straightaway" portions paralleling the runway. The IMU error sensitivities to this oscillatory motion will be examined in the data processing, and the IMU error model revised as required to reflect the sensitivity to the H-19 flight environment.

Type 4 - Level Flight Cruise

Test 1

Level flight, climb IMU evaluation — This test will involve relatively long, sustained level flight missions which will explore the cruise performance of the IMU in the H-19 environment. Such flights will carry the H-19, as shown in Figure 6-4, into areas in which the GSN-5 accuracy will be degraded. Hence, the flight paths are designed to provide specific check points, such as the SPANDAR radar, as control points which will be marked on overflight by the H-19 pilot. The IMU performance evaluation will rely primarily on these single control points in areas of poor GSN-5 coverage, and the emphasis will be on determining total accumulated IMU error upon return to the field area. Updating at descent path entry will be tested in Phase 1B. The GSN-5 beam axis (zero azimuth) will be positioned at 220° for this test to provide maximum coverage of the type 4 flights.

Type 5 Profile - Terminal Area Entry Update

This test series simulates the updating of an aided inertial system upon entry into a flight termination area, say 10 - 35 miles from touchdown, followed by cruise to the landing point and letdown, with additional updating as deemed necessary. The folded trajectory

for this type profile, sketched in Figure 6-5, is designed so that the simulated terminal area entry update occurs at a point near the GSN-5; thus, the update accuracy will be very high, and the degradation of the GSN-5 at long ranges avoided. Following the terminal entry update, a sustained cruise flight to and from the location of the SPANDAR is made (about 13 miles) to simulate the final phase of a flight to the landing area. The H-19 is held on the ground for a 10-minute interval before takeoff to build-up a substantial IMU error so that the accumulated effects of a "cruise" may be simulated, and the update technique effectiveness evaluated. The cruise flight following update will, as in profile 4, be continuously tracked with the GSN-5 to provide data on the IMU performance which will be correlated with type 4 profile test data.

Descent slope entry will provide another opportunity to exercise the update capability. Since the type 5 profiles represent most closely the actual use of an aided inertial system in intercity transportation, variation on the basic updating schemes, such as different frequencies and updated parameters, will be made and IMU performance monitored for each variation.

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7. TEST RANGE AND FACILITIES

The H-19 flight test program will be conducted at the NASA Wallops Isle Test Range located in the Atlantic Coast region near Pocomoke City, Maryland. The test range consists of an airfield with three runways with respective lengths of approximately 4500, 6500 and 7500 feet. In addition to the usual facilities such as control tower, hangars, etc., the airfield is equipped with the GSN-5 radar. The GSN-5 radar is located on the taxiway adjacent to runway 10-28. The FPQ-6 radar site is used as a checkpoint.

7.1 TEST AREA DESCRIPTIONS

The H-19 program ground support equipment and helicopter parking areas will be located north of the runway 10-28 taxiway and east of runway 16-34. Referring to the map of Figure 7-1, these areas are designated as Areas 1 and 2.

Area 1 - Helicopter Parking Area

> This area will be the nominal helicopter takeoff and return point for the flight tests. The IGS ground support equipment (AGE) van and operations van will be located in this area as shown in Figure 7-2. The helicopter will be headed true north and located with the tail clear of the taxiway. Location of the AGE and operations vans will be such as to provide a clear line of site for the GSN-5 and other antennas located in Area 2.

Area 2 - GSN-5 and Equipment Van Location

> The GSN-5 radar antenna will be located on the south edge of the 10-28 taxiway as shown in Figure 7-3. The DTS, DCS and GSN-5 radar vans will be located off the taxiway as shown. The DCS and DTS antennas will be positioned on the antenna platform at the edge of the taxiway so as to have a clear line of sight to the helicopter at all times (including when the helicopter is parked).

7.1.1 Alignment Facility

During preflight checkout, the IMU will be aligned in azimuth by using the porro prism, on the azimuth gimbal, and a T-3 theodolite. Leveling loops in the AGE will be used for vertical alignment. The T-3

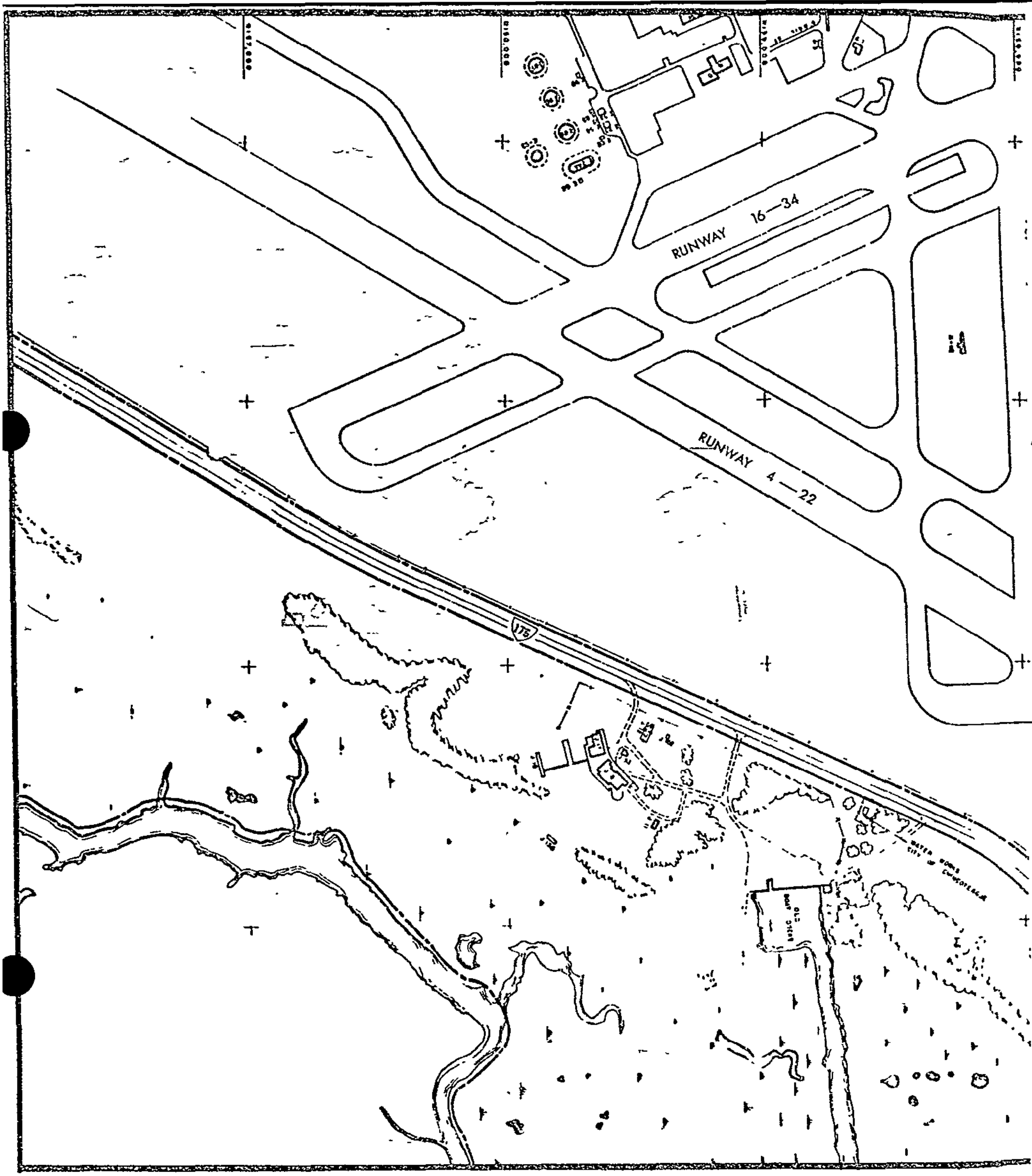
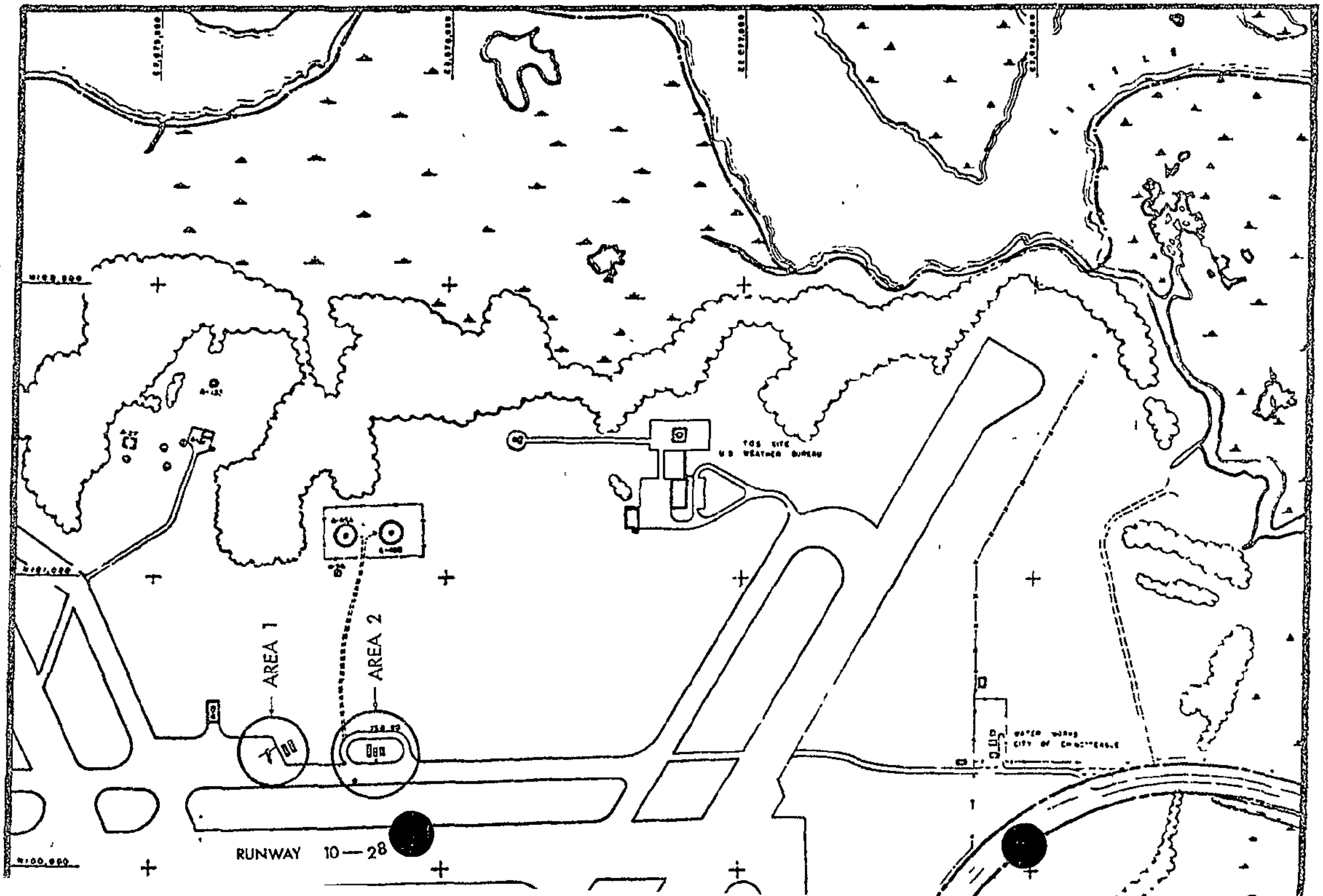


Figure 7-1. Wallops Isle Test Range



FOLDOUT FRAME 2

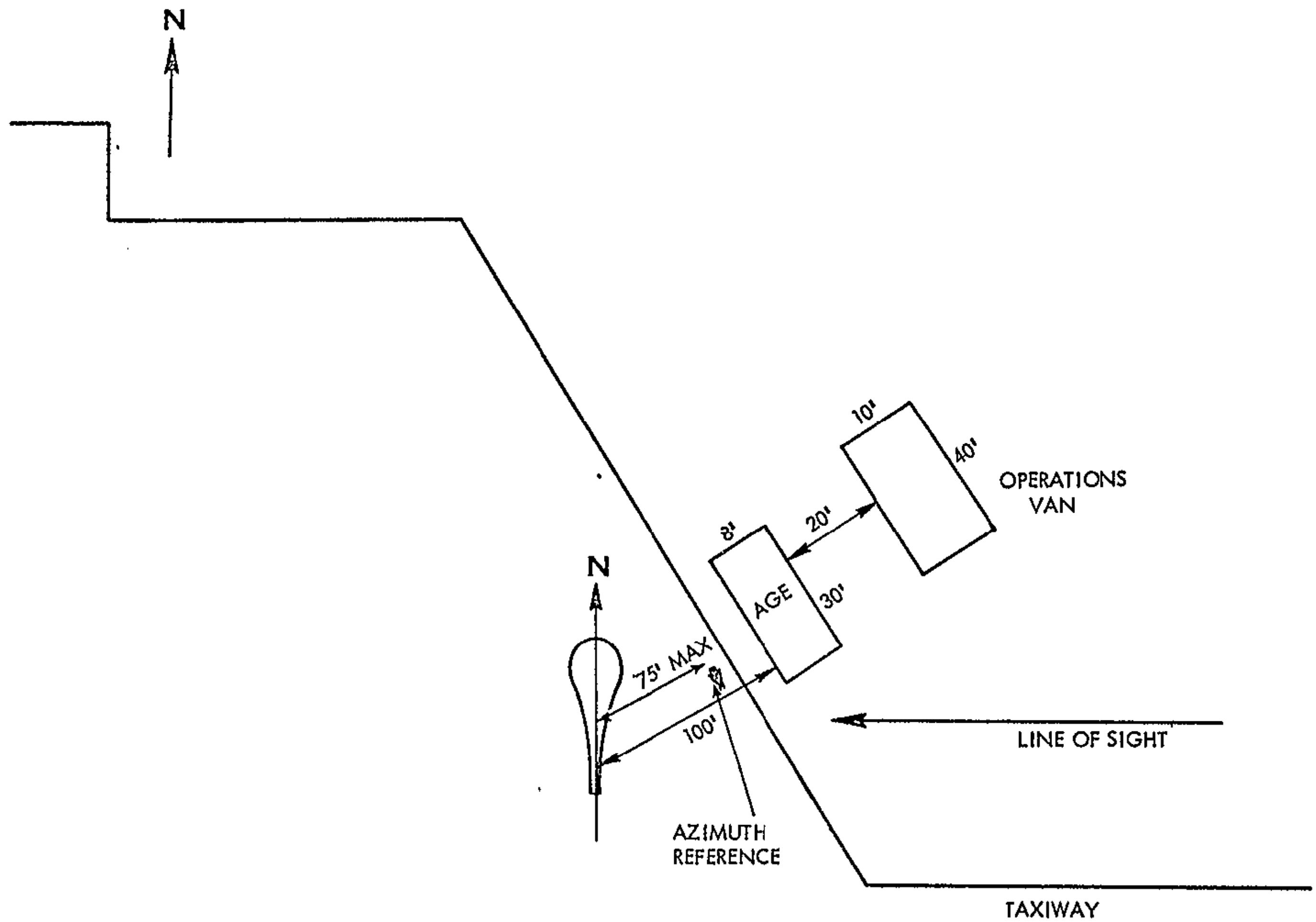


Figure 7-2. Area 1 Layout (Preliminary)

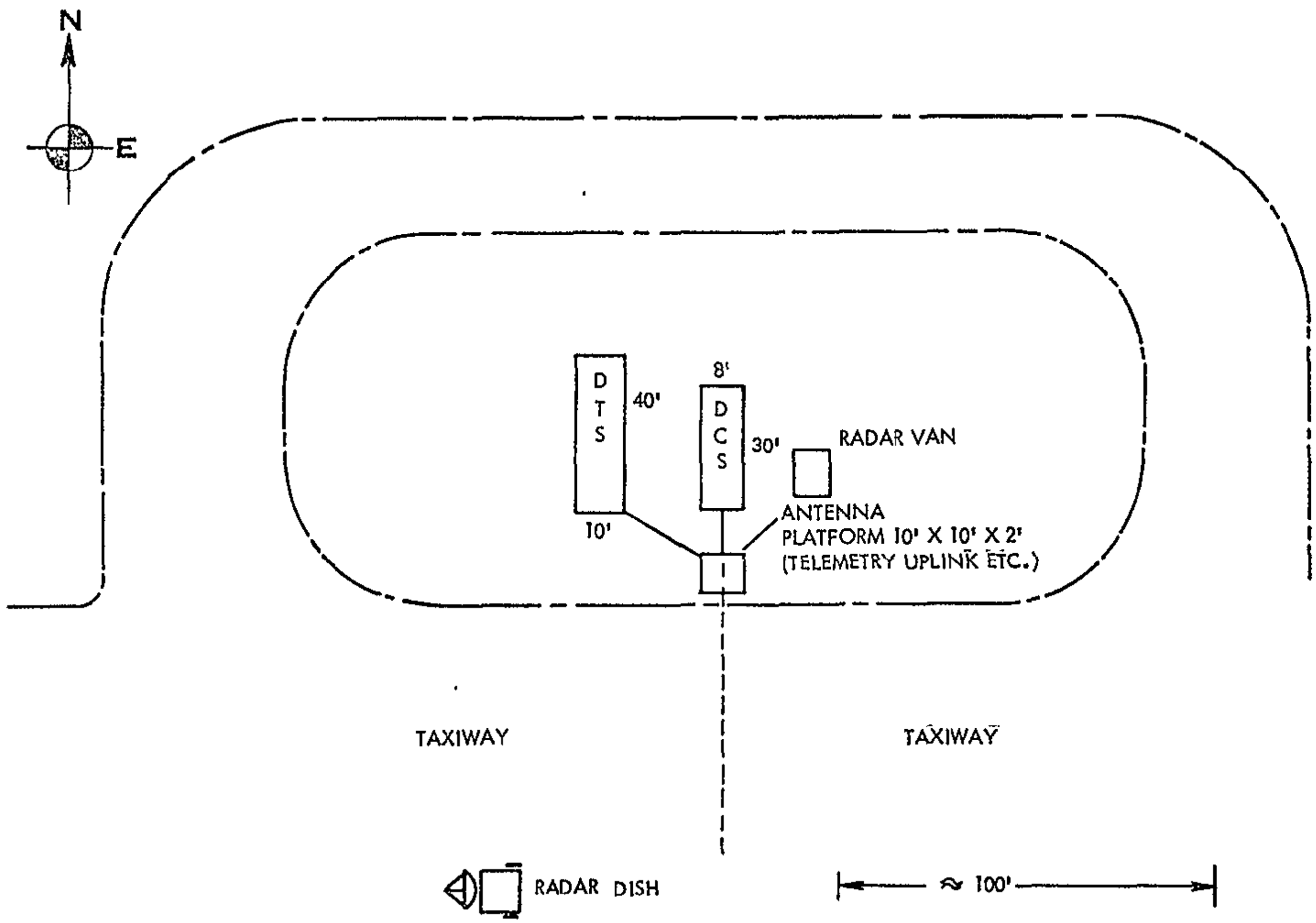


Figure 7-3. Area 2 Layout (Preliminary)

theodolite will be positioned over the azimuth reference mark located in the helicopter parking area as shown in Figure 7-2. Prior to the Phase 1A tests an accurate azimuth reference line will have been established using the azimuth reference mark and a stable structure (i.e., a tower or some other structure 1 → 2 miles away). Accuracy of the baseline will be within $\pm$ 1 min. Also, the latitude, longitude, altitude and gravity constant at Area 1 will be determined.

To facilitate the IMU optical alignment, touchdown pads will be located in Area 1 to assist in locating the helicopter within the viewing constraints of the optical alignment equipment.

7.2 TEST AREA LAYOUTS

As indicated in Section 7-1, the helicopter parking area and ground support equipment for the H-19 program will be located in Areas 1 and 2. A conceptual view of the H-19 test location is shown in Figure 7-4.

Area 1

The AGE van will contain the ground support equipment for the IMU and the flight computer. During checkout and ground operation this equipment will interface with the aircraft through the IGS test cable. Prior to flight and following the preflight initialization, the power is switched to internal, IGS is placed in the inertial mode and the cable disconnected from the aircraft.

The operations (or GSN-5) van will function as the test center and operation headquarters for the test conductor.

Area 2

The DTS van will house the ground telemetry equipment. This equipment consists of 18 racks of recording and monitoring equipment. The capability of this equipment is described in Section 5. The DCS van contains the digital command system equipment, the A/D converter and the master time reference. The DCS equipment consists of six racks of equipment, a control panel, magnetic core memory and two power supplies.

The GSN-5 ground radar van functions as the radar control center. Power to the GSN-5 is supplied from a separate small trailer located relatively close to the radar antenna.

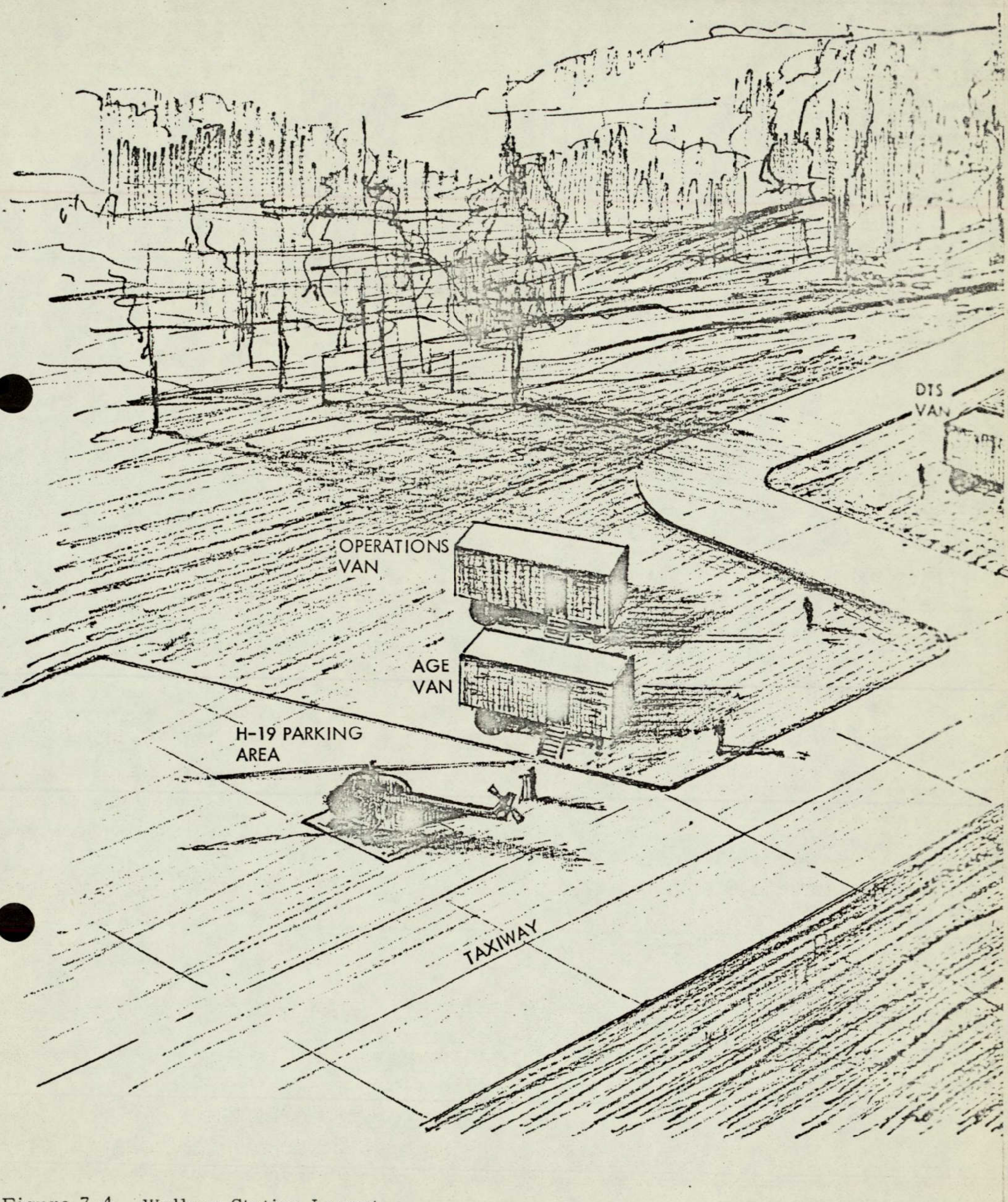
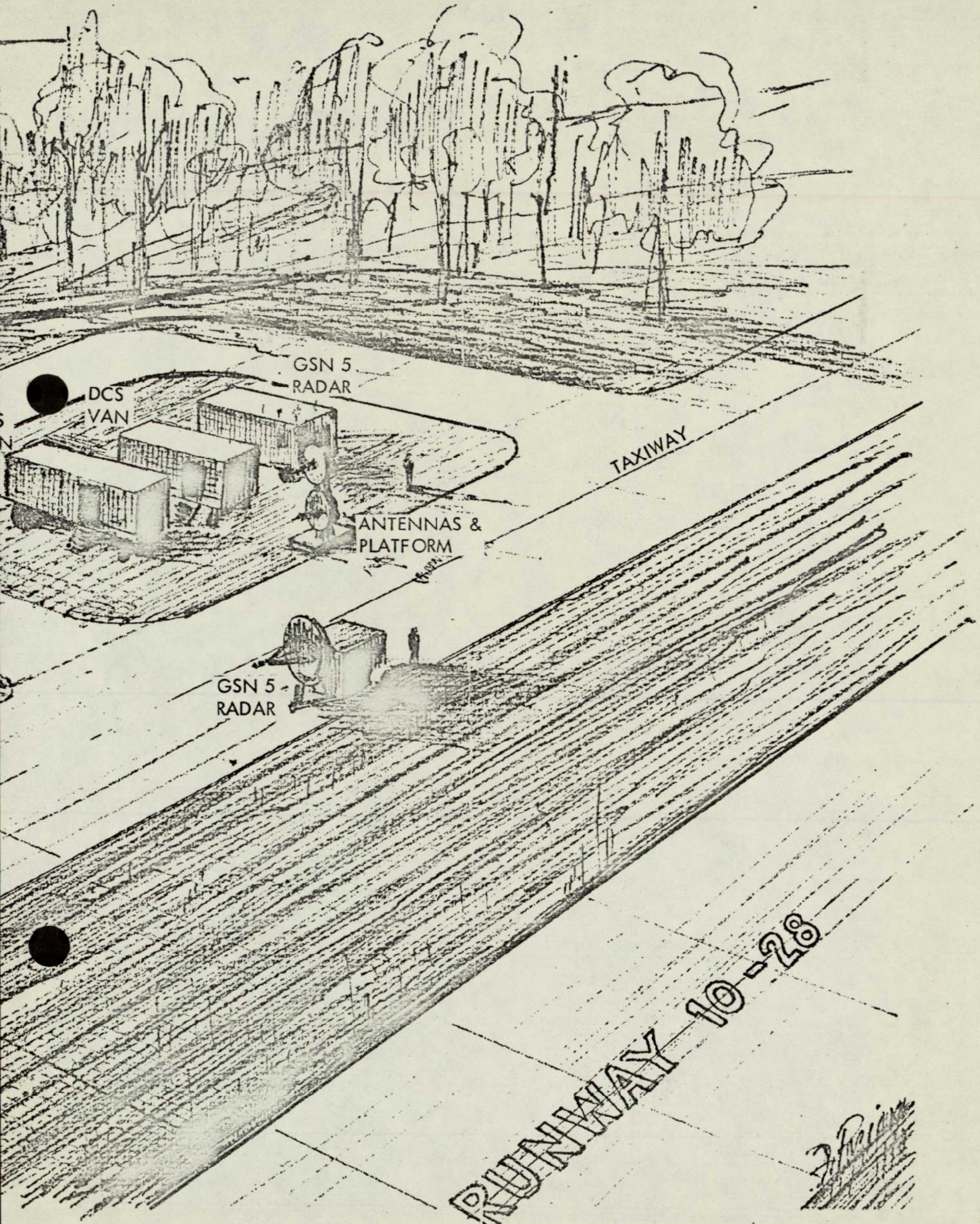


Figure 7-4. Wallops Station Layout
H-19 Program



FOLDOUT FRAME 2

A ground communication system will be utilized to coordinate activities within the test area. Communication between the aircraft and the ground will originate from the operations or GSN-5 van (whichever is selected as the test conductor's flight base of operations.

8. DATA RECOVERY

8.1 PARAMETER LISTS

For quick look and postflight analysis purposes, the following parameters will be available from the flight test data:

A. Gemini Computer Word from Downlink Telemetry

1) Pitch gimbal angle
2) Yaw gimbal angle
3) Roll gimbal angle
4) Sum X accelerometer counts
5) Sum Y accelerometer counts
6) Sum Z accelerometer counts
7) Flight time
8) Flow tag and computation cycle time
9) Radius (to earth center)
10) Earth reference velocity
11) Flight path angle
12) X - ECI position
13) Y - ECI position
14) Z - ECI position
15) Latitude
16) Longitude
17) VX - ECI velocity
18) VY - ECI velocity
19) VZ - ECI velocity
20) Integration time
21) Earth referenced heading

B. Onboard Recorder Tape

These items should be identical to A.

C. GSN-5 Data

1) X (earth fixed criteria)
2) Y (earth fixed criteria)

3) Z (earth fixed criteria)

4) X (earth fixed criteria)

5) Y (earth fixed criteria)

6) Z (earth fixed criteria)

Additionally, a time word will be placed on the tape from the Wallops Station time standard.

D. Environmental Recording System

1) The translational vibration environment amplitudes and frequency range near the IGS.

8.2 DATA RECORDING

8.2.1 H-19-to-Ground Telemetry

The serial PCM telemetry information from the DTS is tape recorded in the DTS van. Although the serial PCM data is converted to parallel in the DTS van for possible display or quick look analysis of the parameters, no provision has or will be made to record the parallel data on tape.

8.2.2 Airborne Recording

The serial PCM data transmitted on the downlink is simultaneously tape-recorded in the H-19. The format of the airborne tape is substantially the same as the ground-recorded except for the subframe - mainframe structure. The on-board recording will provide a secondary or backup source of data to the recorded downlink data.

8.2.3 GSN-5 Data

The direct analog XYZ output of the GSN-5 is available for display on strip recorders but will not be tape recorded. The digital PCM output of an analog to digital converter, which feeds the DCS for uplink transmission, will be the magnetic tape recording point for GSN-5 data. The A/D converters and recorders for this function have not yet been procured; hence, the format specifications have not been fully defined. However, present plans for the GSN-5 tape recording provide for a serial A/D converter output to be recorded in a format similar to the serial PCM recorded on the downlink.

8.3 DATA FORMATTING

Serial PCM telemetry (downlink), serial PCM airborne recorder tapes, and serial PCM GSN-5 tapes will be the basic data sources for the postflight analysis. The postflight analysis programs are configured for IBM 7094 computer operational PCM format conversion from the serial format will be accomplished using conventional pulse shaping, bit synchronization hardware coupled to an IBM 1800 computer. Software for the 1800 will be configured to permit sealing of the data, selection of words and other processing as may be desired. The data flow through PCM formatting process is shown in Figure 8-1. Final format definition and data processing procedures will be detailed in the Data Reduction and Analysis Plan.

8.4 DATA HANDLING

Airborne Recorder Tape

An instrumentation tape will be required for the airborne recorder, and will be supplied on-site. The data handling contractor personnel will install the tape, annotate it and remove the tape for processing its data after each flight.

Ground Telemetry Recording Tape

The DTS van will require an instrumentation tape for recording the telemetered data. The data handling contractor will supply this tape and will install this tape, annotate it properly and remove the tape for data processing after each flight.

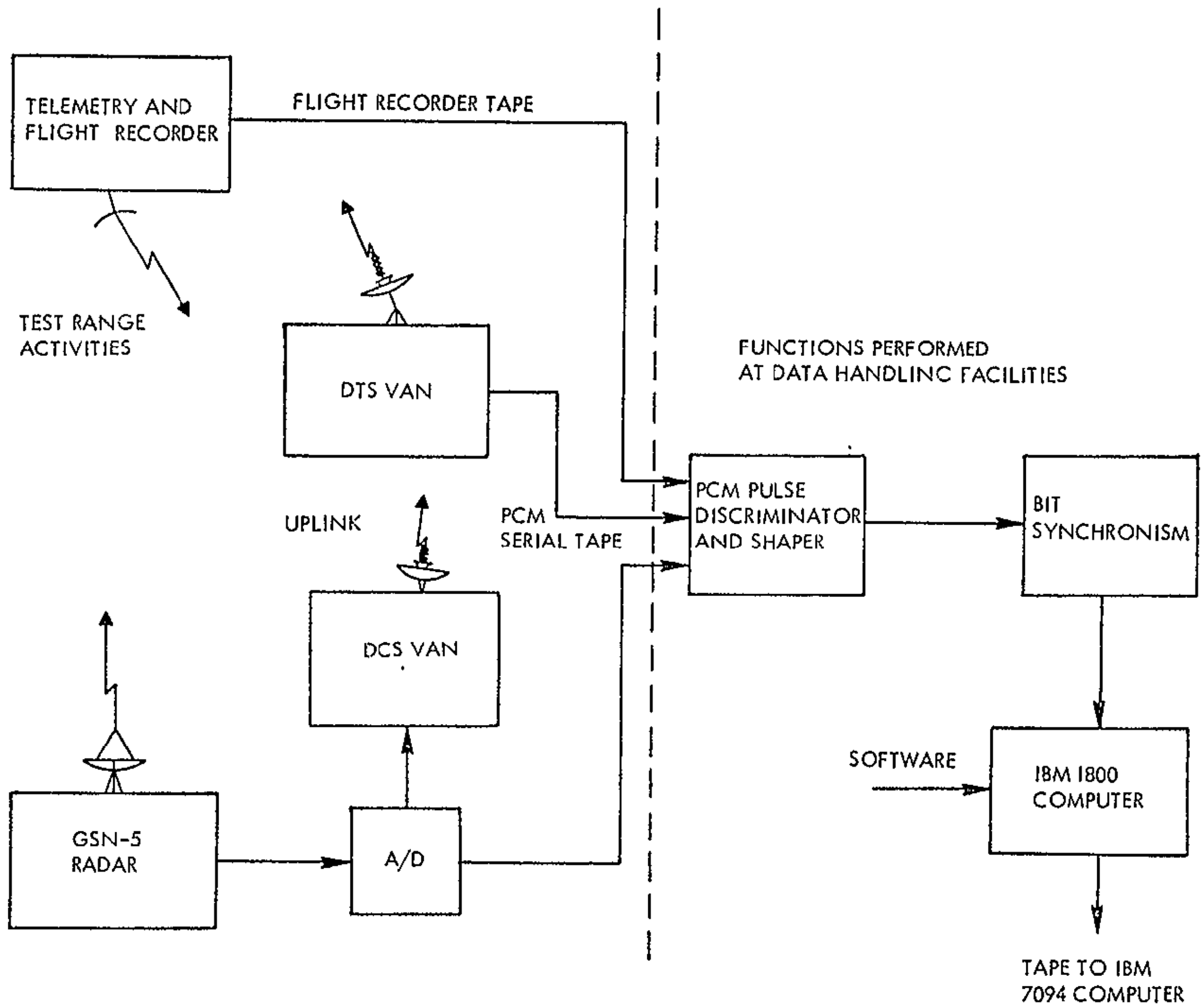


Figure 8-1. PCM Data Flow Diagram

9. DATA ANALYSIS

The function of the data analysis is as follows:

1) Provide techniques for making quick-look evaluation to test performance between flights so that significant anomalies may be detected.

2) Provide evaluation of the postflight data to determine actual errors in H-19, IGS, GSN-5, and data links.

3) Develop display and reporting methods to illustrate performance in an effective manner.

4) Provide a basis for determining the best revisions in test methods and/or hardware specification to meet or improve on success criteria for the test.

9.1 COMPUTER PROGRAMS

Operating computer programs are available to assist in the postflight analysis which will require minor modification to meet H-19 flight test specifics. The programs are:

A. <u>Guidance Data Processor</u>

<u>Input:</u>

1) Raw telemetry observations or onboard recordings

<u>Function:</u>

1) Select parameters from reformatted tapes

H-19/GEMINI POSTFLIGHT GUIDANCE ANALYSIS PROGRAMS*

2) Make timing corrections

3) Scale parameters

4) Write postflight analysis tape.

<u>Output:</u>

1) Listings of necessary IMU parameters

*The programs listed here were used for the Gemini postflight analysis and currently exist at the Software and Computing Center.

2) Postflight analysis tape.

T/M pos, vel, Σ acc counts

B. T/M Edit

Input:

1) Postflight analysis tape from (A)

2) Accelerometer calibration constants (bias, SF, misalignment).

Function:

1) Edit data words

2) Compute accelerometer sensed velocity from accelerometer count data

3) Differentiate and integrate sensed velocity to obtain sensed acceleration and position data.

Output:

1) H-19 sensed accleration profile 2) Reconstructed sensed IGS trajectory 3) Edited telemetered IGS trajectory.	One Tape

C. IMU Error Simulation Program

(May require modifications due to H-19 hardware, alignment, or software changes)

Input:

1) Sensed acceleration profile

Function:

1) Compute IMU trajectory partials (BG) which are psotion and velocity errors which would result from possible IMU error sources.

Output:

1) Tape containing IMU partials (BG).

D. IGS Coordinate Position and Velocity Comparison Program

Input:

1) Tape outputs from B, C, E, and F programs (See Figure 9-1).

Function:

1) Cartesian comparisons, IGS-tracker (See Figure 9-1).

Output:

1) (IGS-tracker) differences on tape

2) Gravity adjusted sensed trajectory tape.

E. Gravity Generator Program

Input:

1) T/M and radar measured H-19 trajectory

Function:

1) Generate gravity corrections for sensed IGS trajectory

Output:

1) Gravity corrections tape

F. Tracking Data Processor

Input:

1) Radar observations

Function:

1) Transforms, interpolates, differentiates, smoothes if desired

Output:

1) ECIG trajectory tape for gravity and comparison programs

2) Natural coordinate tape for (G).

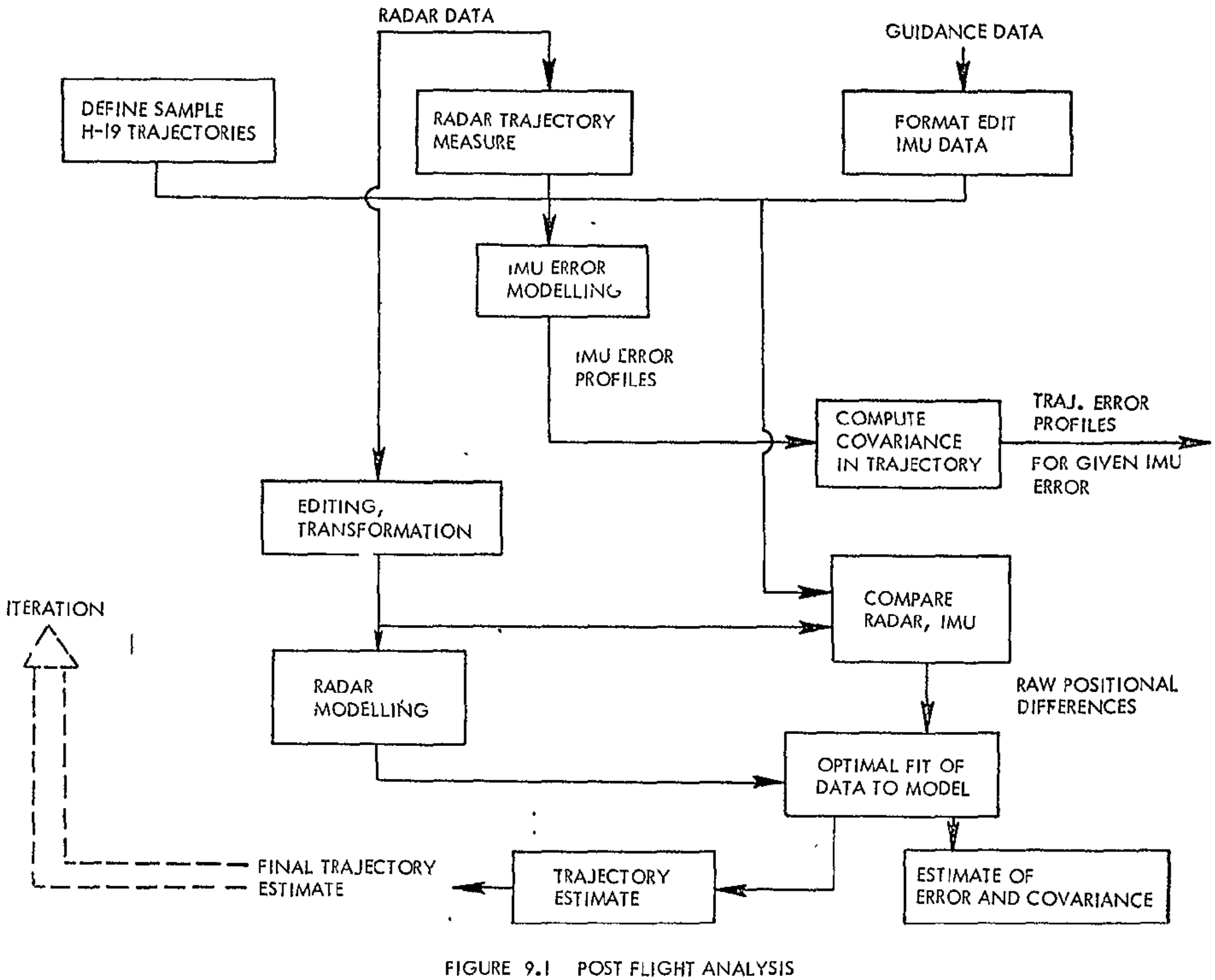


Figure 9-1. Post Flight Analysis

G. <u>Tracking Data Coordinate Comparison Program</u>

<u>Input:</u>

1) Radar observations from (F)

2) Guide trajectory and IMU partials from (D)

3) Tracker survey information.

<u>Function:</u>

1) Compare IGS and radar measurements in radar coordinates

<u>Output:</u>

1) Tape containing residuals (IGS-radar)

2) Tape containing reconstructed IGS trajectory and IMU partials.

H. <u>Tracker Analysis Program</u>

<u>Input:</u>

1) Tape No. 2 from (G)

2) Tracker survey information.

<u>Function:</u>

1) Compute tracker partial derivatives (i.e., measurement errors which would result from unit value tracker error sources).

<u>Output:</u>

Tape containing guidance and tracker partials for input to (I)

I. <u>Regression Program</u>

<u>Input:</u>

1) Residuals tape from (G)

2) Partials tape from (H).

<u>Functions:</u>

1) Combine and scale IGS and tracker partials to determine a "most likely" set of error sources which could have caused the observed IGS/tracker residuals.

Output:

1) Recovered error source coefficients and uncertainties.

9.2 QUICK LOOK ANALYSIS

The quick look analysis will operate under the groundrule that results must be obtainable between flights. Thus, two levels of quick look analysis are defined

Level 1. One hour turnaround (between same-day flight)

Level 2. Overnight turnaround

The primary function of these analyses is to provide the test conductor with an overall general level of test success, and aid him in isolating the location of any errors significant enough to require corrective action before the next flight. The postflight analysis program will be used in an error analysis mode (See Section 9-3). to predict error levels anticipated on the flight tests, which will be major factors in determining test success.

The primary quick look parameters will be:

1) Readout of IMU position (XYZ)

2) Readout of latitude - longitude

3) Readout of heading

4) Readout of radius.

The direct readouts will be compared to plots prepared preflight which will contain the predicted values plus various level of uncertainty profiles. During the flight planning stage, the simulation of the postflight analysis will generate expected error answer for the directly readout parameters. Quick-look preparation will include making overlays on the appropriate strip chart scales of n σ performance; hence, the quick look output can contain an estimate of the parameter "n."

More meaningful quick-look evaluation can be obtained if simple desk calculating machinery is used to obtain required coordinate transformations. The routines and constants in such calculation can be

prepared preflight and their operation is well within a one hour time constraint. The inclusion of a desk calculator or simple programmable calculating machine on site is recommended for quick look.

9.3 POSTFLIGHT ANALYSIS

The postflight analysis will emphasize computer program data reduction to provide meaningful test evaluation. The primary flow of analysis procedures is shown in Figure 9-1. The steps in the postflight analysis are also applicable, with modification to accuracy prediction, so that the influence of flight configuration or hardware changes may be determined. The postflight analyses are planned as follows:

1) Estimated H-19 acceleration, velocity and position profiles (for error analyses),

   or

   measured trajectory profile driver IMU error modeling program and radar error modeling program which generate unit partial derivatives of system measurements with respect to error terms.

2) Required time bias adjustments are made between radar and IMU data. In addition, the radar data is transformed into platform coordinates.

3) Gravity profile compensation is applied to adjust the radar data.

4) IMU and radar data are compared in platform coordinate to generate residual profiles. These are plotted and compared with the unit error curves to provide preliminary estimates of errors.

5) Machine fits of the residual data using the error model profiles, previously derived, to estimate IMU and radar error model coefficients. Fixed control points, such as touchdown, are weighted into this solution. The error coefficients and their covariances are estimated.

6) The guidance data is compensated for the recovered error coefficients and final corrected radar-IMU residual set generated.

7) If required, an iteration to correct the error sensitivity terms for the difference between the final trajectory and initial trajectory is made.

8) For the covariance estimated in the system error coefficients, a computation of 1σ trajectory error along the flight profile is made, and compared with requirements.

9) Phase 1B update commands will be analyzed by correcting the IMU error sensitivity functions to reset terms included in the updating.

10) Final output of the analysis will include plots of initial and final residuals, error level estimates, trajectory uncertainty estimates and a general evaluation of system performance.

10. SCHEDULES

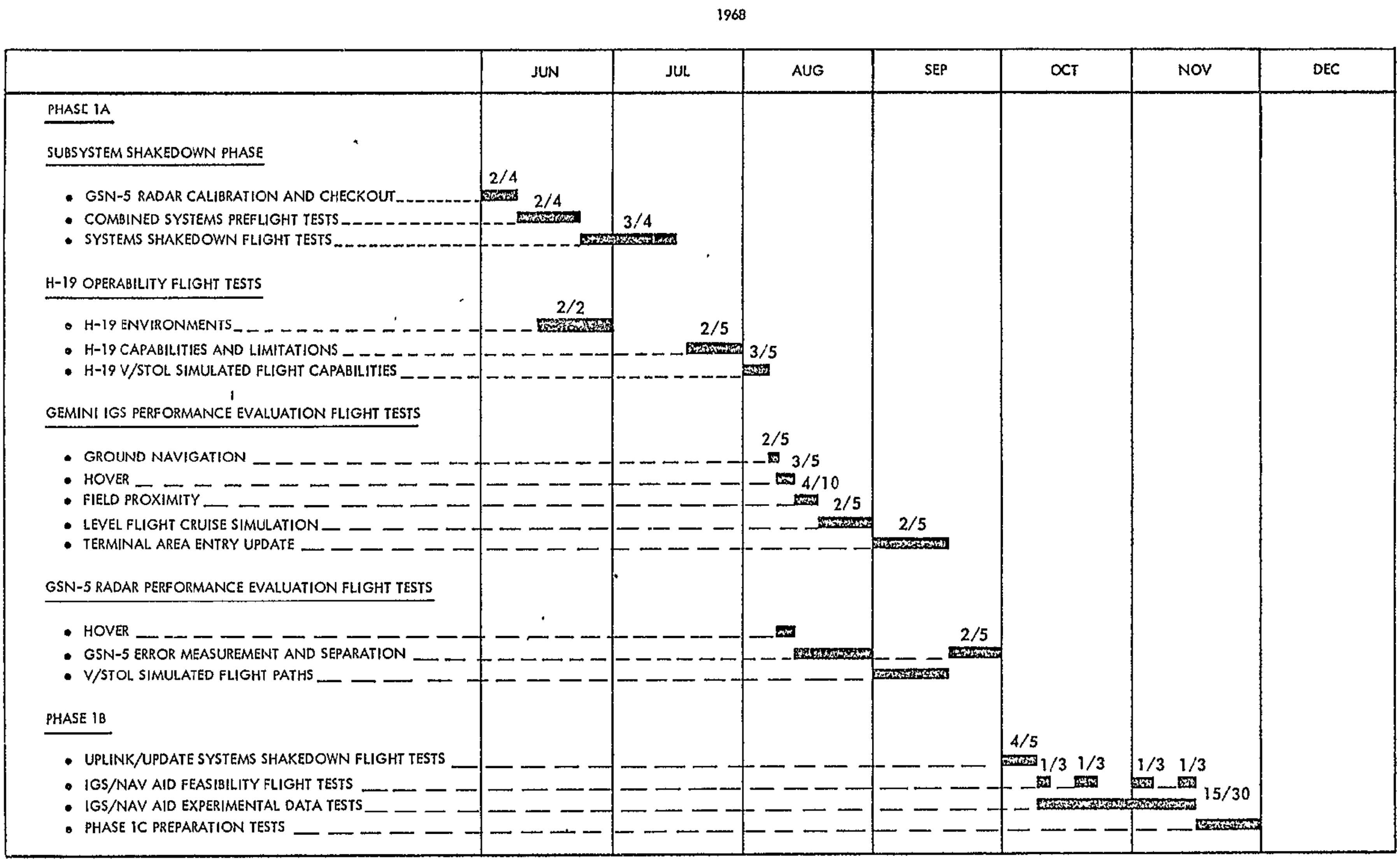
Figure 10-1 delineates the major test activities of the Phase 1A and 1B test schedule (as described in paragraphs 6.2 and 6.4) for the aided-inertial system program.

Consulting Figure 10-1, Phase 1A is divided into four major categories as follows: Subsystem Shakedown, H-19 Operability Flight Tests, Gemini IGS Performance Evaluation Flight Tests and GSN-5 Radar Performance Evaluation Flight Tests. Within each major category minor test phases are defined.

As seen in Figure 10-1, Phase 1B is divided into four major test categories.

The number of successful flights deemed necessary to support each minor test phase is identified in brackets above the time bar for that phase.

The schedules shown are based upon a forty hour single shift work week excluding Saturdays, Sundays and holidays. Should contingencies arise sufficient flexibility is present in the planned schedule to permit work-arounds.



NUMBERS INDICATE MIN-MAX NUMBER OF SUCCESSFUL FLIGHTS

Figure 10-1. Phases 1A and 1B Test Schedule for the Aided-Inertial System